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CYCLOPÆDIA OF USEFUL ARTS,

Mechanical and Chemical,

MANUFACTURES, MINING, AND ENGINEERING.

VOL. I.

ABATTOIR TO HAIR-PENCILS.

G. Dodgson. S. Bradshaw

The Britannia Tubular Bridge over the Menai Straits.

CYCLOPÆDIA

OF

USEFUL ARTS & MANUFACTURES,

Edited by

CHARLES TOMLINSON.

The Bell Rock Lighthouse

GEORGE VIRTUE, LONDON & NEW YORK.

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VOL. I.

ABATTOIR TO HAIR-PENCILS.

WITH

AN INTRODUCTORY ESSAY ON THE GREAT EXHIBITION OF THE WORKS OF INDUSTRY OF ALL NATIONS, 1851.

THE WHOLE ILLUSTRATED BY FORTY STEEL ENGRAVINGS,

AND TWO THOUSAND FOUR HUNDRED AND SEVENTY-SEVEN WOOD ENGRAVINGS.

LONDON:

JAMES S. VIRTUE, CITY ROAD, AND IVY LANE.

VIRTUE & CO., JOHN STREET, NEW YORK.

c. 1853

TO

EDWARD COWPER, ESQ.

PROFESSOR OF MANUFACTURING ART AND MACHINERY,
IN KING'S COLLEGE, LONDON.

My dear Sir,

Your profound knowledge of the Useful Arts and Manufactures, and your clear and happy method of explaining and illustrating them in your public lectures, would alone account for my desire to dedicate to you the First Volume of this Cyclopædia. But I am also stimulated thereto by the kindness which you have so steadily shown me during many years, and the approbation with which you have encouraged my frequent attempts to explain to the popular mind, in a systematic manner, the beautiful and complicated processes of the Useful Arts.

Entertaining a profound respect for my subject, I have endeavoured in this, as in former publications, to treat it in such a manner that my readers may gain real instruction. You are well aware that this is not to be done by evading difficulties, but by fairly meeting and endeavouring to overcome them. Slight sketches of what is seen at the surface of our manufactories, during one or two visits, may furnish entertainment, but will neither advance the reader in useful knowledge, nor assist the student in his inquiries. The object of all teaching, whether oral or written, should be to instruct and elevate. You have shown how well this object may be attained in the lecture-room: those who are engaged in the responsible office of writing for the people should be actuated by the same earnestness and zeal, and should endeavour to attain a similar depth and completeness.

With a well stored mind, and an earnest purpose, the public teacher cannot fail to interest his hearers or his readers, and to take them with him in carefully studying and bringing out the details of human ingenuity, and the processes of the Useful Arts, which are, indeed, calculated to excite admiration, especially when it is considered that some of the most important of them were known in the earliest times, and seem, like language, to have been the result of Divine inspiration.[1]

(1) Genesis iii. 23. Exodus xxxi. 2—6; xxxvi. 1. 1 Kings vii. 14. Isaiah xxviii. 26, 29.

In no other way can we account for the origin of the varied and complicated processes which the chemist, the metallurgist, and the machinist of modern times have appropriated and explained, but which were known and successfully adopted many ages before chemistry, metallurgy, and mechanics existed as sciences; while even now there are processes in the Useful Arts which science is incapable of explaining.

Hence it is that I approach the Useful Arts with the same kind of reverence with which I regard Science. In assisting human progress and intellectual culture the services of the one are scarcely inferior to those of the other. There is, and ever must be, an intimate relation subsisting between them; and, perhaps, no one has more successfully illustrated that relation than yourself. The wants of the Industrial Arts give healthful employment to Science: the knowledge of the one often supplies, I will not say the ignorance, but the deficiencies, of the other; for Science herself is progressive, like the Useful Arts, and is, in fact, like all human effort, which first accumulates, then generalizes, and uses the last generalization as the vantage-ground from which a wider range of intellectual horizon may be viewed. Art and Science in cordial union become ministers of usefulness to humanity, and of corresponding advantage to each other; some of the richest and choicest possessions of Science having been free gifts from the Useful Arts, and some of the most important processes in the Useful Arts having been invented, or simplified, or rendered more productive by Science.

That you may long continue to instruct us, and to promote the cordiality of the union between Art and Science, is the earnest prayer of

Your obliged and obedient Servant,

and attached Friend,

CHARLES TOMLINSON.

Bedford Place, Ampthill Square.

PREFACE.

THE first Volume of this Cyclopædia completes the first half of the industrial alphabet; the subjects included in the letters A to G occupying as much space as those between the letters H and Z, to which the second volume will be devoted.

In a prospectus issued in March 1850, the Editor stated the principles which would guide him in the conduct of this Work, and he thinks it right to repeat on this occasion the substance of what he then said.

It is necessary to distinguish between Useful Arts and Manufactures which depend on the application of scientific principles, and Trades which depend chiefly on manual skill and dexterity. In a large number of trades the material, as supplied by the manufacturer, is merely cut into shape, and then joined together. The manufacturer, on the contrary, has to convert raw materials into finished fabrics, by means of a series of complicated and instructive processes. Hence the employments of the manufacturer rank higher than those of the mechanic, and hence in the present work attention is particularly directed to arts and manufactures in which scientific principles are involved.

It is likewise necessary to understand the connexion which really exists between the Useful Arts and Science. A distinction commonly made between Art and Science, supposes the one to be eminently practical, and the other purely theoretical. The practical man, who supposes that he owes everything to experience, not unfrequently applies the term *theorist*, by way of reproach, to the man of science; while the latter, who imagines that his best knowledge is based upon theory, often regards the practical man as one whose skill and judgment are limited to a small range of routine operations. This feeling is injurious both to Science and to the Useful Arts, for there is no doubt that they are mutually dependent, and that the advance of one must lead to a corresponding advance of the other. A large number of manufacturing processes have preceded scientific theory; they were discovered after repeated trials and failures of other processes: a slow and costly method necessarily standing in the way of improvement. Moreover, the processes thus discovered were kept secret, and formed the *mystery* of the trade, gradually revealed to the young mechanic in the course of his apprenticeship. Nor could the master pretend to do more than teach the processes in their prescribed order: the reasons for them, and for one particular order rather than another, he could not teach, and hence the *art and mystery* gradually assumed a fixed and consolidated character, apparently incapable of improvement.

But, as Science advanced, light was gradually introduced into the domain of the Useful

Arts; sight and intelligence were given to processes which had hitherto been groping in the dark; while Science herself obtained rich stores of facts, which have since been moulded into many a useful theory. The theory itself (which is nothing more than a number of truths connected by one or more common principle) thus became not only the benefactor and improver of the Useful Arts already in existence, but a broad foundation on which new processes and new Useful Arts could be erected. When once this connexion between Science and Art was fairly recognised, the theoretical and the practical proceeded together hand in hand; the theoretical saving the practical from many useless efforts and ridiculous failures, and the practical furnishing fresh facts to the theoretical for higher generalizations. This intimate relation between Science and the Useful Arts is now so generally recognised, that every unprejudiced practical man must admit that he owes something to Science. His own practice is, in fact, the result of scientific theory. He is probably practising that which fifty years ago existed only in books and memoirs.

England has just reason to be proud of her scientific, as well as of her so-called practical men; of Newton, Priestley, Cavendish, Black, and Davy, as well as of Smeaton, Brindley, Arkwright, Telford, and Watt; and as the labours of the one merge into and assist the progress of the other, it would evidently be improper, even if it were possible, to confine the details of a work devoted to the Useful Arts to those of a merely practical character. If such a course were to be attempted, we might succeed in bringing before the reader a vast collection of facts, but he would miss the tie (the scientific principle) which connects and binds them together. Isolated facts form the gossip of Science and the Useful Arts: facts, connected by principles, constitute their logical reasoning.

The Editor has frequently had occasion to address the popular mind on the subjects to which the present Work is devoted, and it has always been his endeavour to adjust his teaching so as to meet difficulties, and not to evade them. He has never desired to make his writings appear easy, by the omission of those details which, however difficult to explain in a popular manner, are yet of great importance to the reader. There is, of course, a good deal which cannot be fully entered upon without a considerable knowledge of mathematics; but there is a mixed mode of laying out a subject, which proceeds on the supposition that the reader is acquainted with the merest elements of mathematics. This gives the writer the advantage of avoiding the two extremes of the merely popular and the abstruse and theoretical; he can, in such case, show the value of facts in a scientific point of view, the modes in which they have been obtained, the principles which they tend to illustrate or establish, and the degree of certainty with which they may be admitted.

It is the object of the Editor, in the present Work, to make use of language as popular as the nature of the subjects will admit of. The principles on which the Useful Arts and Manufactures depend will take the most prominent place; while processes, patent inventions, and details of machinery, will be made subordinate to this higher aim; for, if the reader be made acquainted with the scientific principle on which a process, or a machine, is based or constructed, he will find the practical details comparatively easy, and will be able to judge for himself more accurately of the value of variations and improvements whenever he may find them.

Most of the processes in the Useful Arts and Manufactures already described, or still remaining to be described in this Work, the Editor has himself witnessed; and if he should succeed in conveying to the reader a portion of the instruction and pleasure which he has derived from his visits to the manufacturing towns of Great Britain, he will feel that one of

the objects for which he undertook this Work will have been accomplished. A series of factory visits during several years have enabled him to describe the general mechanical arrangements of such establishments, the various processes therein carried on, the regulations respecting hours of labour, and the means employed by many enlightened manufacturers to promote the moral welfare of the people entrusted to their care. On this last head he would gladly enlarge, so as to bring into public notice the systematic efforts to this end which are being recognised more and more as a duty, and are also happily exemplified in the practice of some eminent firms not legally bound by those enactments which apply to factories, strictly so called. By observing the definition of the word *Factory* as given in the article under that head at page 629, it will be seen that a large proportion of the establishments, commonly so called, are not properly included in that term, and consequently do not come under Government inspection. It is, therefore, especially pleasing when such firms are found, on their own responsibility, and with a just view of the important position in which they stand to their work-people, coming forward generously and actively to superintend all measures, educational, intellectual, and moral, which may appear to favour the best interests of the employed.

The general character and successful working of such plans are well illustrated by the following example, which is here given, not by any means as a solitary instance of wise and judicious employment of influence, but as one of the most recent and satisfactory of those which have come under the Editor's notice. At the Belmont Works, Vauxhall, which is the principal establishment belonging to Price's Patent Candle Company, a series of beneficial efforts have been carried on by the Messrs. Wilson, managing directors, for the improvement of the condition, spiritual and temporal, of the seven or eight hundred workpeople under their care. The efficient and well-conducted day and evening schools which form a leading feature in these efforts, had their origin in circumstances thus stated by Mr. James Wilson, in a letter to the Educational Committee appointed by the Company, in 1851, for the purpose of considering questions relating to the nature and extent of the education afforded at their works, the outlay incurred, &c. "The schools began in a very humble way, by half-a-dozen of our boys hiding themselves behind a bench two or three times a-week, after they had done their day's work, to practise writing on scraps of paper, with worn-out pens begged from the counting-house. The foreman of their department encouraged them; and as they persevered, and were joined by other boys, he begged that some rough movable desks might be made for them. When they had obtained these, they used to clear away the candle-boxes at night, and set up the desks, and thus work more comfortably than before, although still at great disadvantages as compared with working in any ordinary school-room." This purely voluntary effort on the part of the boys was encouraged by gifts of copy-books, spelling-books, Testaments, and prize-books, from the Messrs. Wilson, and finally by the clearing, adapting, and furnishing an unused portion of the factory buildings as a school-room, capable of accommodating 100 boys. Here the work of education was still entirely the work of the boys themselves; so much so, that the prayers with which the school closed were always read by themselves. But as the numbers increased, difficulties arose, and the necessity for a stronger government, and more advanced teaching than could be supplied among themselves, became apparent. It was not, however, until the principle of self-government had been fairly and fully tried, that the school, at the earnest request of the elder boys, was placed under authority; and even then, the exercise of that authority was often guided by a general vote.

The school thus commenced was an evening school, but the new room was soon made use of to remedy an evil arising out of the peculiar circumstances of the trade, namely, the taking on a number of additional boys at certain seasons for the "night light" manufacture,

and then letting them go again when the pressure was over. Such boys were frequently taken away from schools in the neighbourhood to enter the factory, and when discharged, did not so readily return to them, but idled about and learned bad habits in the streets, till the time of fresh employment in the factory came round. On the establishment of a day-school on the premises, the younger boys were passed from factory to school, and from school to factory, on the shortest notice, and thus constant discipline and authority were maintained over them. Into this school, also, were admitted a number of boys not old enough for factory work, but eligible to it when sufficiently trained, the best scholars being always first selected for that purpose. This " nursery ground to the factory " appears to be of great importance to the interests of the Company, obviating the necessity for taking on, at an hour's notice, untried boys, whose carelessness in the delicate work of making night lights might entail much mischief and trouble, before it could be discovered exactly where the evil originated. In the case, also, of boys old enough to work, a few weeks' probation in the school is found valuable, as making known who are steady enough to be trusted with factory work, and who are too careless to be employed without loss. The fact of the master having at his disposal so great a prize for good conduct, as the sending a boy down to work and to receive wages, gives him much greater power over his scholars than can be obtained in an ordinary school. With respect to boys already at work in the factory, their attendance at the evening school was for some time in small numbers compared with the total number employed. But the pleasure afforded to the scholars by tea-parties, which were given by Mr. Wilson in the new school-room, soon led others to join, and subsequently better attractions were provided, by way of connecting harmless gratifications with attendance on school. The new school-room, which at first was more than sufficiently large, became in time so much over-crowded, that all the desks had to be removed from it, and the boys wrote on pieces of stiff pasteboard held in their hand on their knees. A second room, therefore, became absolutely necessary, and as there was no space available elsewhere, it was built on the top of the first. A railway-arch was also fitted up as a school-room, and there the boys and girls of the night-light factory were schooled by turns. All these plans are in operation with a degree of efficiency and success that must be most encouraging to the promoters of the work. The gratifications afforded to the scholars are happily described in the letter already referred to, and great prominence is given to the game of cricket, yet it was a melancholy occasion which decided the time for beginning to teach it to the boys. " In the summer of 1849," says Mr. Wilson, " the cholera came, and it was fearfully severe in Battersea fields and the lower part of Lambeth, where numbers of our people live. For a time the first thing every morning was to compare notes as to the relations whom the men and boys had left dead or dying on coming to work, and in the latter part of the time no doctors were to be had, as they were all knocked up. Before it got very bad, we got good medical advice, as to whether any precautions against it were possible for our boys, and decided that fresh air and exercise out of the factory were the best preventives. We therefore closed the school entirely, and a gentleman (Mr. Symes) having most kindly let us take possession of a field which was waiting to be occupied by a builder, we set to work hard at learning cricket after working hours. I say learning, for cricket is not a game of London-boys of the class of ours, as was proved by the fact of hardly any of, even the elder ones, knowing anything at all about it when we began." This step was attended with the best results to the general health of the boys, so that only one fell a victim to the disease, though many lost relations living in the same house with them. " Always when the game was finished they collected in the corner of the field, and took off their caps for a very short prayer for the safety from cholera of themselves and their friends, and the tone in which they said their Amen to this has always made me think, that although

the school was nominally given up for the time, they were really getting from their game so concluded more moral benefit than any quantity of ordinary schooling could have given them. They also met every morning in the school-room at six o'clock, before beginning work, just for a few minutes, to give thanks for having been safely brought to the beginning of the day, and to pray to be defended in it."

Subsequently a rough unenclosed field of six-and-a-half acres was taken, at a rent of 40*l.* per annum; and was fenced in by the gratuitous and voluntary labour of the men in their evening hours, a large portion round the edges being allotted out for gardens, and the middle retained for cricket. The present state of affairs, as it respects the game, is very satisfactory. The boys, by diligent practice, have become expert players, and have even ventured to challenge the men (who have a cricket-club of their own) to trials of skill. On the first trial of twenty-two boys to eleven men, the former, to the great astonishment of themselves as well as the rest of the factory, beat the men in one innings, and a subsequent trial with sixteen to eleven was equally successful. A prize book with the score marked in the beginning of it, is given to each one on the winning side, in the chief cricket matches. The expense of the cricket-ground, gardens, &c., for three years, was 249*l.*; but the managing directors consider the money well bestowed not only in the bodily benefits,—the strength, activity, and quickness of hand and eye acquired by the players, but in the moral results. "Any one observing our first-class boys, in one of their matches," says Mr. J. Wilson; "their entire freedom from rudeness of conduct or language, in fact, their really gentlemanlike behaviour towards each other, will feel that the moral training quite keeps pace with the physical." And here follow some remarks on the relations between employers and employed, which appear to the Editor to be so just and important, that he gladly gives them further circulation in these pages. After speaking of the beneficial effects of mixing together, boys, men, and masters in the cricket-ground and gardens, and the intimate acquaintance thus produced, Mr. J. Wilson goes on to say,—"Everybody, especially those who happen to be most ignorant of the whole subject, such as some of the well-intentioned persons who have been backing up the Amalgamated Society, is ready to preach about the necessity of this knowledge of each other by masters and men, but I suppose only masters can know the extreme difficulty of getting to be on a footing of anything like personal friendship with the men of a factory when the number is large, however anxious they may be to get on such a footing. In business hours, both masters and men are too busy to have time for gossiping, and directly business is over, the best men go, and ought to go, straight home to their families, not to see the masters again till business hours are again begun. And although, speaking from our experience here, the masters are always most cordially welcomed in the families, and the notion of such visits being considered an intrusion is a libel upon both masters and men, yet anything like general visiting is a simple physical impossibility. What little time the masters can give to visiting, is sure to be required by those families of the boys which have no male head to take care of them, and therefore their visiting has no tendency to bring them into acquaintance with the men under them; except, indeed, in cases of dangerous illness. With the boys and young men brought up in the factory, the case is quite different, for there is no need of their going straight home to their families when work is over, so the masters can keep them in the school-room or elsewhere, and gain their affections, and get great influence over them. With many of our young men we are, I trust, upon terms of true and deep personal friendship, such as will last for life, although, of course, when they in their turn become fathers of families, there will be the same want of much intercourse as with our present men; but when you once know a man thoroughly, and he you, the mere moving about in the same work, with a kindly word or look when you happen to be thrown together, quite keeps up the cordiality of feeling."

Heartily wishing for employers generally a state of feeling towards their workpeople such as the above remarks indicate, the Editor would likewise direct attention to the summer excursions, which form another pleasing feature of the Belmont arrangements. The first experiment of this sort was made in June 1850, when one hundred boys went down by train to Guildford, and spent a fine day in strolling about the beautiful neighbourhood, having their meals on the grass, playing cricket, and attending church service, (for Mr. Wilson has a happy and cheerful method of bringing religion into everything). This passed off with such perfect success, that in the following summer an expedition on a grander scale was planned and carried out. On Saturday, 21st of June, 250 boys started before six in the morning by a small steamer from Vauxhall Bridge, to join a large steamer lower down the river, in which to go to Herne Bay. Not one out of ten of this number had ever seen the sea before. "The sea is not so perfectly sea at Herne Bay, as the country is country at Guildford; but still it was an exceeding delight to them, and as the wind freshened a little on the way back, they (which was not quite so delightful) felt as well as saw it; and the majority showed that they did so. All the first who felt qualmish, were greeted with a general cheer to console them, but another half-hour made a sad alteration in the proportion of the cheerers to the cheered. The day was as perfect as that of the previous year, and as the water was quite smooth going down, and as the boys had so heartily enjoyed the voyage, the run on shore, and the bathe there, the half or three-quarters of an hour's sickness coming back did not much matter; but, on the contrary, would make them understand the sea all the better." This second excursion was as successful as the first, and will not easily be forgotten, were it only for the complete flaying of many of their faces by the sun. The expense of the first excursion was 28*l.*; that of the second was 48*l.* A third excursion promises, through the kindness of the Bishop of Winchester, to exceed the foregoing in interest, for it includes an invitation to Farnham Castle, where the old keep, the gardens, park, hop-grounds, &c., will afford abundant sources of pleasure, while the hospitality of the good Bishop, and his hoped-for presence, will constitute great attractions and subjects of long remembrance for the happy boys whose good conduct in the school shall entitle them to this privilege.

To crown the whole of the admirable arrangements of this factory, the services of two clergymen are secured, one to perform the services in the chapel, the other for the religious work of the factory itself, consisting of early morning and evening prayers, teaching in the schools, and visiting of the families.

Much of the above relates to the plans adopted for the benefit of the younger members of the factory; but there is also a society entirely formed by the men, and managed by themselves, for mutual improvement; "and from the character of the managers," says Mr. Wilson, "we are sure that its power will be exerted on the side of religious, as well as intellectual advancement." The particular means adopted for the intellectual, moral, and social advancement of the members of this society, are the establishment of a reading-room and library, the formation of classes for reading, writing, music, &c., and the institution of scientific and other lectures. All these efforts have been made under the sanction, and with the active co-operation of the Messrs. Wilson; while the benevolent writer of the letter referred to has likewise defrayed the whole expense of schools, salaries, buildings, excursions, &c. for three years out of his own private resources. The total expense thus incurred was 3,289*l.* To the honour of the Company, all these educational and other efforts have been cordially adopted as their own at a meeting of the Proprietors, held 24th March, 1852, when a sum of 1,200*l.* per annum was freely voted for the future carrying out of these measures. The sum spent by Mr. J. P. Wilson is also to be reimbursed; but that gentleman, with characteristic singleness of purpose, refuses to receive it into his own pocket, but devotes it as the commencement of a building fund, for

rearing a chapel near the factory, with school-rooms on one side, and rooms for the Mutual Improvement Society on the other. This act of generosity is in perfect consistence with a long course of self-denying exertion, arising out of convictions which are thus forcibly put in the sequel to his letter, and which are earnestly recommended to the consideration of all individuals or companies employing numerous hands.

"What are the duties of the Directors of a Trading Company, and indeed the duties of the Company itself? Is such a Company only bound to give an honest living to the young people who work for it, leaving all other care of them to the general institutions of the country, and to parental or other individual exertion? Or is it bound to take also a moral charge over them, and to provide in the factory system itself counteracting influences to those evil ones which are sure to spring up and spread rapidly in any collection (and by the mere fact of its being a collection) of young people of this class if left to take care of themselves? For my own part, I should view an affirmative answer by our Proprietary to the latter of these questions as a matter of national importance. That which is looked upon as forming the chief danger of England at this moment,—the separation of the owners of capital from those by whose labour it fructifies,—can nowhere exist more strongly than in a Joint-stock manufacturing Company,—one such as ours, with its three or four hundred capitalists, and more than twice that number of workers; the capitalists and the workers as completely separated from each other as if they belonged to different nations. Now, if into the very business system of such a Company arrangements can be introduced which shall completely counteract this danger, by forming the working part of an association to such a character as will keep them in full sympathy with the class of their employers, by their possession of the same ideas and feelings, and to some tolerable extent the same intellectual education, and if these arrangements shall be declared by a deliberate vote of the Proprietors to be an essential part of their system of business, and as such to be attended to by the Directors, to whom they entrust that business as carefully as anything else in it, am I not right in saying that the recognition of such a principle by one powerful Company, will be a matter of national importance?" Every reflecting person must answer in the affirmative, and rejoice that the vote alluded to *was* passed, and that the rights of the working-classes to that general consideration on the part of their employers, which includes their moral and spiritual instruction, should thus be publicly recognised by one of the most influential Trading Companies of the kingdom.

DIRECTIONS TO THE BINDER.

VOL. I.

The Introductory Essay, pages i. to clx., to come immediately after the Title-page and Preface.

The Britannia Tubular Bridge *to form the Frontispiece to Vol. I.*

The Bell Rock Lighthouse, *Engraved Title-page to Vol. I.*

VOL. II.

The Great Britain Leaving Liverpool, 1853, *Engraved Title to Vol. II.*

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A VIEW OF THE GREAT INDUSTRIAL EXHIBITION IN HYDE PARK.

INTRODUCTORY ESSAY.

ON THE GREAT EXHIBITION OF THE WORKS OF INDUSTRY OF ALL NATIONS, 1851.

In taking a leisurely survey of a well-stored and well-arranged museum, the thoughtful observer cannot fail to be struck with the endless variety of forms, and the wonderful adaptations of means to certain pre-appointed ends, which abound in the kingdoms of nature. Every single specimen, whether it be of an animal, a plant, or a mineral, has a history to tell, full of design, abounding in instruction, and replete with beauty. All these varied forms, gathered from all parts of the earth, grouped with the method and order of a scientific mind, are, to a certain extent, exponents of the method and order of the Divine Architect, who, in planning the fabric and willing the existence of the meanest of His creatures, had in view certain wise and benevolent ends, which it is our duty and our privilege to study, and as far as possible to understand. It may in many cases be difficult to see the uses of the beings and objects on which so much care has been bestowed, and for whose propagation and preservation so many precautions have been taken; but we must bear in mind, that the use of an object does not always mean its direct application to the wants or the pleasures of man. It doubtless has its uses in the great scheme of nature, and as such the naturalist regards its economic application as of secondary importance. Hence if rightly viewed there is not a single object, however mean, which does not in some way or other appeal to our sympathies, excite our interest, and confirm our belief in the constant care of a protecting Providence.

The majority of mankind, however, feel most interest in that which appeals to their daily experience, and to their human sympathies. The intellectual is not so likely to be popular as the practical. The fine arts have but a limited range; the useful arts are unbounded. Science can only be cultivated by the few; the applications of science can be, to some extent at least, appreciated by all. Moreover, the products of the useful arts, wherever practised, are full of meaning and suggestion to the unlearned as well as to the skilful. They are connecting links between the various scattered members of the great human family. The savage in the forest wild bakes his bread, brews a fermented drink, tans his leather, weaves his cloth, or carves his spear, by processes which are familiar to ourselves, and which form the basis of our more perfect and more extensive operations. In addition to the distinctive features impressed upon industrial products by climate, soil, political institutions and other causes, there is always impressed upon them the stamp of humanity—the action of the human mind, and the work of the human hand; and this excites our interest and awakens our regard.

It was a grand idea to provide for the industrial arts that which had been so long and so well done for natural history and the fine arts, namely, a museum; to collect into one vast enclosure, and under one vast roof, the industrial products of all nations and of all climes; to group and arrange these, as far as possible, according to a systematic method calculated to arrest and inform the observer. Our country has done this; and while she has pursued, with respect to her own products, her own plans of classification and arrangement, she has also allotted to other nations certain spaces to fill up and arrange, each according to the taste and fancy of its contributors. Such an idea, we repeat, was a grand one, and the carrying of it out has, under the Divine blessing, been no less grand, satisfactory, and we trust beneficial to the cause of peace and civilization.

Section I.—Origin of National Industrial Exhibitions.

The Exhibition of the Industry of all Nations may be regarded as the full and perfect development of an Institution, which during the last half century has greatly contributed to advance the arts and manufactures of France. This subject is so important in all its bearings and relations, that we cannot do better than lay before the reader a brief sketch of the origin and history of those Expositions of National Industry in France, in which the manufactured products and industrial resources of the country were at certain periods focalized, as it were, and brought under the notice not only of the public and of the manufacturers themselves, but of eminent scientific individuals, well calculated by their attainments to decide on the merits of the articles exhibited, and to report to government the progress made by the industrial population of the country.

It appears from a statement made by the Marquis d'Avèze, that in the year V. of the Republic, 1797, that gentleman was requested by the Minister of the Interior to undertake the office of Commissioner to the Manufactures of the Gobelins (tapestries), of Sèvres (china) and of the Savonnerie (carpets). On visiting these establishments, the marquis found the workshops deserted; for the artisans had been in a starving condition for two years, while the warehouses were full of the results of their labours, and no commercial enterprise came to relieve the general embarrassment. It then occurred to the marquis that if these and other objects of industry of the national manufactures could be collected together in one large exhibition, a stimulus might be given to the native industry, and thus relief be afforded to the suffering workmen. The plan was approved by M. François de Neufchateau, the Minister of the Interior, and the chateau of St. Cloud was appropriated to the purpose. "In a few days the walls of every apartment in the castle were hung with the finest Gobelin tapestry; the floors covered with the superb carpets of the Savonnerie, which long rivalled the carpets of Turkey, and latterly have far surpassed them; the large and beautiful vases, the magnificent groups, and the exquisite pictures of Sèvres china, enriched these saloons, already glowing with the *chefs d'œuvre* of Gobelins and the Savonnerie. The Chamber of Mars was converted into a receptacle for porcelain, where might be seen the most beautiful services of every kind, vases for flowers,—in short, all the tasteful varieties which are originated by this incomparable manufacture." The 18th Fructidor was the day fixed for public admission, but previous to that time a number of distinguished persons in Paris and many foreigners visited the Exposition, and made purchases sufficient to afford a distribution to the workmen, whereby some temporary relief was afforded to their necessities. But on the very morning of the 18th, the walls of the city were placarded with the decree of the Directory for the expulsion of the nobility. The chateau of St. Cloud was given into the custody of a company of dragoons, the Marquis d'Avèze was in the proscribed list, and thus ended the scheme which had promised so well.

Early in the following year, however, (1798,) on his return from proscription to Paris, the marquis resumed his labours. The place selected for the Exposition was the Maison d'Orsay, Rue de Varennes, No 667. The objects collected consisted of rich furniture and marqueterie by Boule, Riessner, and Jacob;[1] clocks and watches by L'Epine and Leroy; porcelain and china from the manufactories of Sèvres, of Angoulême and of Nast; richly bound books; silks of Lyons; historical pictures by Vincent, David, and Suvé; landscapes by Hue and Valencienne; flowers by Vandael, and Van Pankouck; and many other objects of an equally luxurious and aristocratic character; all tending to prove that in banishing the aristocracy from Paris, the Government had banished the chief patrons of French manufacture. The Exposition was exceedingly attractive and successful, and the Government accordingly determined to adopt the idea and to carry it out on a grand scale. An admirable opportunity was afforded on the return of Napoleon from the successful termination of the Italian wars. On the same spot in the Champ de Mars on which the army had celebrated the inauguration of the collection of Italian spoils, and only six weeks after that fête, the nation erected the "Temple of Industry," around which were arranged sixty porticoes filled with objects of use or of beauty. The

(1) See the article Buhl-work, p. 258 of the Cyclopædia.

Exhibition remained open only during the last three complementary days of the year VI. of the Republic; but it excited the greatest enthusiasm throughout the country. The merits of the several exhibitors were entrusted to the decision of a jury composed of nine men, distinguished in science and in art; and this plan was found to work so well, that it was continued in subsequent Expositions, the only change being, to increase the number of jurors. The names of some of the manufacturers in the prize list are of European reputation; as for example, that of Breguet, connected with the progress of watch and clock making in France; Lenoir, the inventor and maker of mathematical instruments; Didot and Herhan, who so greatly improved the art of printing; Dilh and Guerhard, whose manufacture of painted china rivalled that of Sèvres; Conté, celebrated as a mechanist and engineer, who first applied machine-ruling to engraving; Clouet and Payen, so well known for their chemicals; and Denys de Luat, among whose cotton yarns were some of the then extraordinary fineness of No. 110.[1]

The success of this Exposition was so complete that the Executive determined in future to have every year an Exposition, which should include the provinces. Accordingly, they addressed letters to the préfets of departments, requesting them to form committees whose office it should be to determine what local products were worthy of being forwarded to Paris at the public expense, and of becoming eligible to compete for a prize either of 20 silver medals, offered by the Government, or of one gold medal, to be awarded to any one who should have opposed the most formidable rivalry to British manufacture.

Although it had been decided to have annual Expositions, yet there was an interval of three years between the first and the second Official Exposition. During this time the Consulate had succeeded to the Directory, and the First Consul preferred his title of "Member of the Institute" to any other. Accompanied by his illustrious friends Berthollet, Monge, and Chaptal, Napoleon visited the workshops and great factories of Paris, Rouen, Lyons, Milan, Brussels, Liège, and Aix-la-Chapelle, stimulating all to progress, and distributing rewards. The second Official Exposition took place in the Quadrangle of the Louvre, under elegant porticos erected for the occasion. Its chief features were the improvement in the quality of wool as a raw material. Cottons spun *à la Mulljenny* were exhibited. The carpets of Sallandrouze; the china of Sèvres; the earthenware of Sarreguemines; the morocco leather of Choisy-le-Roi, which surpassed in beauty that of Turkey itself; and the perfect printing of Didot, Herhan, and Piranesi, claimed the attention of, and were especially commended by, the jury. Two hundred and twenty exhibitors were admitted to the competition,—about double the number of those in 1798. Seven who had already obtained gold medals were set aside, and the eight best manufacturers placed in the second order in 1798 were separated from the list, in order to reserve the silver medals for their equals in industry. Hence arose the custom of voting only confirmation of previous rewards in favour of those who honourably maintained their already acquired position. Altogether 10 gold, 20 silver, and 30 bronze medals were awarded. It was on this occasion that JACQUARD obtained a bronze medal, and subsequently an annuity of 1,000 francs, which was ultimately increased to 6,000.

The third Exposition took place in the following year, 1802. In this the number of competitors had again doubled, and the greatest exertion and activity were displayed to make the Exposition worthy the character of the nation. The Exposition had by this time lost its exclusive and aristocratic character. Articles in common demand were largely exhibited, and among the striking features of the collection were the extended application of mechanical and chemical science to facilitate production, and consequently to reduce greatly the price of articles in popular demand. Twenty-two gold medals were distributed for such capital inventions or improvements as the hydraulic-ram of Montgolfier; the stocking-frame of Aubert; the silk-spinning-machine of Vaucanson, and the chemical products of Decroisilles of Rouen, and Amfry and Darcet of Paris. One of the immediate results of the extended popularity of these Expositions, was the establishment of the *Société d'Encouragement*, which has greatly assisted in developing the inventive genius of France, and in the application of abstract science to the wants and requirements of manufactures. In the origin of this society only four prizes of the

(1) See COTTON, page 469 supra.

value of 3,600 francs (less than 150*l.*) were offered: these have been so much increased, that they now amount to many hundred thousand francs.

The fourth Exposition, in 1806, was well calculated to illustrate the advance and extension of French industry under the influence of the master mind of Napoleon, and with the science and skill of such men as François de Neufchateau, Chaptal, Berthollet, &c. In every department of textile fabrics great advances had been made. In this Exposition appeared for the first time the printed cottons of Mulhausen and Logelbach. Silk, thread and cotton lace, blonde, cloth, mixed goods, and the beautiful imitations of Cashmere shawls, all marked the progress of the nation in the useful arts, notwithstanding the incessant wars of the period.

The manufacture of iron by the aid of coke instead of charcoal, and that of steel by an improved process, gave tools to the workman, and arms to the soldier. The application of the power of transferring ornaments from copper plates to the surface of porcelain, aided much in lowering the cost, and consequently in increasing the demand for this important article.

An interval of thirteen years took place between the fourth and the fifth Exposition. The leading feature in this Exhibition was the improvement in the art of metallurgy. The great iron-works of the Loire contributed excellent castings; while the forges of Grossouvre (department of Cher) sent iron not hammered, but rolled. Anchors, wire, tools, jewellery, plate, and plated goods; damascene work, bronze, steel, stereotype plates, metallic oxides for colouring glass, &c., showed the great progress that had been made in manufactures in metals. Calico printing was well illustrated by Daniel Kœchlin: while Raymond Lyon, the inventor of the process for fixing Prussian blue in silk dyeing; Widmer de Jouy, celebrated for his green dye, and others, showed how textile fabrics might be greatly improved in beauty without being made more costly, by the continued progress of chemistry in its applications to the arts.

The sixth Exposition, which took place in 1823, marked the progress which had been made in the application of the improved manufacture of iron to machinery and construction, and the consequent development of Civil Engineering as a profession. A model of the first French suspension bridge, designed by Messrs. Séguin, intended to cross the Rhone between Tain and Tournon, was exhibited.

After an interval of four years, the seventh Exposition showed the influence which steam, as a motive power, was beginning to exert on manufactures. The goods contributed showed an improvement in evenness and regularity of finish; the low prices at which they could be delivered, not only greatly extended the home consumption, but laid the foundation, in many departments of production, for a very considerable export trade. Thus the manufacture of merino, which fifteen or twenty years before had scarcely existed, had now so much increased, that 15,000,000 francs' worth were annually disposed of. The expansion of the manufacture of shawls, silks, tulle, and blonde had been equally remarkable. With respect to the production of silk, an important problem had been resolved. Hitherto it had been confined to the departments of the South, which were supposed to be alone favourable to its cultivation; but it had gradually extended to the central departments, and appeared to be advancing to some of the northern districts. While the raw silk was much purer, the processes of winding and throwing had been greatly improved. Many varieties of new stuffs had been produced from spun silk, and mixed fabrics of silk and wool were especially admired in this Exposition. Cotton-printing was now adapted to the production of cheap goods, and the printed ginghams attracted special notice. The application of machinery to making paper in great lengths, soon affected the manufacture of paper-hangings, and enabled the superior taste displayed by the French, to rival and ultimately to supersede the English production in this art, which had hitherto found favour. In the department of engineering, the results of Vicat's scientific study of natural and artificial cements now began to appear. The manufacture of plate-glass had been improved, and the mediæval processes for staining and painting glass had been revived and improved by modern chemistry.

In the eighth Exposition, which took place in 1834, a steady progress was to be traced in almost every department of manufacture;—in silk, in cotton-printing, in flax-spinning, in tools and chemicals of every kind. Among the chief novelties may be mentioned paper-hangings

printed from cylinders, by Zuber of Mulhausen; the revival of the arts of enamel and niello by Wagner; the formation of elastic tissues by means of india-rubber; the production of artificial ultramarine by Guimèt; the revival of the art of wood-engraving, and the attempt to rival the excellence of Boule and Riessner in marqueterie and inlaid work.

The ninth Exposition held in 1839, illustrated the steady development of success in manufactures, namely, the production of vast quantities of goods at the lowest price, or as it is concisely expressed, "large sales and small profits," a principle which had not been received with much favour in France. In this Exposition the principal points regarded by the jury were, 1stly, Inventions and improvements classed according to the importance of their results as affecting manufacture; 2dly, The extents of the factories and their topographical situation; 3dly, The actual and commercial quality of the goods; 4thly, Cheapness attained by increased facilities of production.

The adoption by the nation of this popular business theory was to be traced mainly to four causes:—1. The improvements which were being constantly effected in machines, and the supply, through upwards of 50 engineering firms, of steam-motive power to any extent. 2. The progress of popular education by means of municipal libraries open to all readers, of commercial and drawing schools, of local museums, of free exhibitions of works of art, &c., and the liberal rewards and aid given to any desirous of prosecuting studies serviceable to the community, but not remunerative to the student. These gratuitous educational means so long in operation had developed the intelligence of the lower orders, and given to the mind of the French artisan something of the tone and feeling of the artist. 3. The theory of commerce as connected with political and social economy had been developed chiefly by the Alsatian manufacturers, whose productions in this Exposition filled a vast saloon appropriated to them. 4. The interest which these periodical Exhibitions had excited throughout France, and the publication of admirable critiques upon them, respecting the nature, quality and relative excellences, manufacturing and artistic, of every object intended to supply the ordinary and extraordinary wants of the people. Mr. Wyatt well remarks, that "from the opportunities of comparison afforded by these institutions, *demand* received the same lessons as *supply*, and thus, the two working together, ministered to one another's deficiencies, and mutually assisted in one common progress."

Among the raw products exhibiting features of novelty or interest the jury particularly referred to the native silk, native nitre, the marbles of the Pyrenees, the lithographic stones discovered in France, the introduction of stearine, the fine wool, and the various qualities of iron stone. Among the machinery the jury especially referred to the success which had attended the production of steam-engines, Jacquard looms, endless paper machines, chronometers, well-boring instruments, wool and cotton spinning apparatus, and sawing and planing machines. In manufacturing processes, steel, glass of every description, and leather, were reported to have made very remarkable progress; the arts of lithography and engraving on wood were admitted to have materially assisted in popularizing fine art, and thus improving the taste of the people.

The tenth Exhibition, held in 1844, is said to have been the most successful of the series, and to have illustrated in the most decided manner the influence of long-continued peace on the industry and productive powers of France. In every department of manufacture were exhibited specimens of great beauty and utilitarian perfection, illustrating the ingenuity of a people cultivated by long study and habit in the highest degree to appreciate excellence as *consumers*, and equal to the task of supplying it as *producers*. In his address to the King at the fête held for the celebration of these industrial victories gained by mind over matter, Baron Thénard, the President of the Central Jury, spoke of the wonderful progress that had been made by the French nation in the peaceful arts. "Industry," said he, "pursues its steady, onward movement: deeply conscious that hesitation would be inevitable retrogression, it unflinchingly redoubles its efforts to advance,—to win new conquests of peace and prosperity." The great chemist then enumerated the most important points in which notable improvements had been made. He spoke of the progress of steam navigation; of the distillation of salt water; of the perfection of iron casting; of the application of new systems of warming and ventilation; of electro-metallurgy; of the manufacture of the best flint glass for astronomical

purposes; of pyroligneous acid; of sulphate of soda; of muriate of potash; of artificial manures; of white lead; of sulphuric acid; of dyes and pigments; of silk; of sugar. The lighthouse system of Fresnel was also spoken of, and he mentioned the increase in the supply, from national resources, of raw silk, of wool, sugar, and flax; but most especially did he direct his Sovereign's attention to the amazing advance which had been made in the construction, not only of machines, but of those powerful engines by which machines are made,—by which iron is shaped with perfect ease into a variety of useful forms. "When, in addition to these great and material acquisitions, we remember," says Mr. Wyatt, "that in all those handicrafts which rise from the industrial, almost into the department of the *fine*, arts,—that in silver and bronze working, in jewellery, ornamental modelling, and designing in every fabric, and in every material, France in 1844 exhibited such a display as no other country could possibly have brought together, we cannot but feel that the benefit derivable to her citizens and to the world, from an inspection of this gorgeous collection of her products, must have been one of the greatest it has ever been the happy privilege of any one country to bestow upon the industry and producing powers of the world at large,—stimulating at once universal education, peace and commerce, and repressing ignorance, aggression, and vicious idleness."

It is worthy of remark that in this Exposition were exhibited specimens of the beautiful art which was introduced by Daguerre, and now perpetuates his name.

In this Exposition no fewer than 3,960 manufacturers exhibited, and of these 3,253 were more or less honourably recognised by the jury, whose Report is one of the most elaborate and skilful of the series from the commencement of these publications.

After an interval of five years came the eleventh Exhibition. In those five years a monarchy had been swept away, an uneasy Republic erected on its ruins, the country a prey to civil discord and distracted by socialism. Arrangements were, however, made for giving to this Exposition an air of greater magnificence than any which had preceded. The area of the building (exclusive of an enormous agricultural shed) was equal to about 5 acres, $2\frac{1}{2}$ roods; the number of exhibitors amounted to 4,494, and that of the central jury to 64. In this Exposition live stock and agricultural produce were, for the first time, admitted to compete for prizes. In his circular, addressed by M. Tourret, the Minister of Agriculture and Commerce, to the Presidents of the Agricultural societies, he states that hitherto agriculture has only been represented in these displays of the national wealth by some agricultural instruments and dressings, and some few samples of wool and silk. "The Government of the Republic has resolved to employ every effort likely to lessen and remove this relative inferiority. It is, indeed, to the credit of agricultural industry that it furnishes manufacturers with the elementary materials of the greater portion of the products to which they put the finishing stroke: it is equally the right and the duty of agriculture to vie with manufacture in the merit, value, and variety of its productions: in short, agriculture should prove its equal aptitude in bringing forth raw materials, and perfecting the fabrication of all produce in which it is concerned."

It is remarkable that previous to this Exposition the idea was proposed and rejected, which has been carried out with so much success by ourselves, namely, to invite other nations to contribute, in order that the French nation might be made acquainted with the skill of those nations with which they so often come into competition in foreign markets. "Should we bring together and compare the specimens of skill in agriculture and manufactures now claiming our notice, whether native or foreign, there would doubtless be much useful experience to be gained, and above all, a spirit of emulation, which might be made greatly advantageous to the country." All who wish well to France must regret the rejection of this enlightened proposal; but when we remember how severely her trade and manufactures suffered from the effects of the last revolution and of the civil war consequent thereon, we may well excuse the mistaken policy. The proposition that every man has the right to demand from the state a day's work and a day's wages, was adopted, and found to be a ridiculous mistake. The employment of the working population must depend upon the prosperity of manufactures, and these cannot continue in a state of activity unless there is a large foreign demand and a considerable export trade. So long as France continues to close her ports by means of high protective duties

against the produce and manufactures of other nations, so long must she continue to manufacture only or chiefly for herself, in which case the supply will exceed the demand, and the elements of revolution will continue to exist in large masses of discontented *ouvriers.*

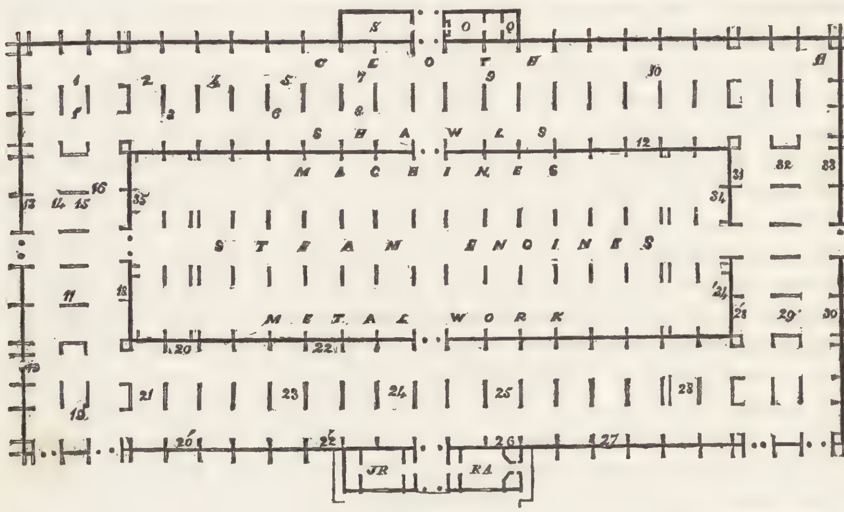
The building erected for the purposes of the Exposition of 1849, was situated on the same site as that occupied by a similar building in 1844. The Carré de Marigny on which it was placed, is a large oblong piece of ground abutting on the main avenue of the Champs Elysées. The architect was M. Moreau. The whole plot covered a parallelogram of about 675 by 328 feet English, round the outline of which was a gallery about 90 feet wide, divided into two avenues by a double range of pilasters. In the centre of each avenue was a set of stalls, placed back to back for the exhibition of merchandise; and both between the central pilasters and round and upon the walls other objects were placed, so that on traversing either of the four gangways (each about 10 feet wide) the visitor had objects on either side for inspection. In the part of the building appropriated to large machinery, this system could not of course be carried out with the same regularity. In the building erected for the Exposition of 1844, also by M. Moreau, the whole parallelogram was left as one magnificent hall, within which were placed the most important objects: in the building of 1849, the parallelogram was divided by two transverse galleries, thereby forming three courtyards. The central one, about 140 feet square, was open to the sky; in the middle was an elegant fountain placed on a platform of turf, and around were sheds for the exhibition of flowers and horticultural ornaments and implements. One of the lateral courts (each of which was 80 feet by 140) received a large collection of objects in metal-work, cast-iron, &c., and in the other was an immense reservoir, in which all the drainage from the roofs was collected, so as to form a supply of water for immediate use in case of fire. The shed for agricultural produce and live stock extended to a length rather greater than the width of the great parallelogram, and was about 100 feet wide. The whole of the building was of wood, but the roofs were covered with zinc. "One of the most striking defects in the plan of the building," says Mr. Wyatt,[1] "was the total impossibility of converting it, for any great national purpose, into a vast hall, in which a multitude might assemble to witness such an exhibition as the bestowal of the prizes. In no position could more than a fourth of the whole extent be seen at one view, so that not only was the effect of a possible *ensemble* entirely lost, but the stupendous effect of one enormous impression of grandeur on entering was perfectly sacrificed to a fancied regularity of plan. Another great disadvantage was the impossibility of adding to the beauty of the effect by the additional galleries, and the acquisition of more space to be appropriated in the event of the contributions proving more numerous than was expected. One peculiarity, which architecturally was most distressing, was, that a system of *sham* seemed to preside over all the ornaments and construction. Great *carton-pierre* trusses which supported nothing—painted bas-reliefs to imitate bronze—fir covered all over with paper to make it look like oak,—were all unnecessary and wasteful professional forgeries. If each simple material had been allowed to tell its own tale, and the lines of the construction so arranged as to conduce to a sentiment of grandeur, the qualities of *power* and *truth* which its enormous extent must have necessarily ensured, could have scarcely failed to excite admiration, and that at a very considerable saving of expense. The agricultural portion of the building was by far the best in design, though comparatively rude; but unhappily, since the exhibition was a very poor one, (the provinces being scarcely at all represented,) almost twice as much accommodation was provided as was needed."

The influence of the Revolution had a deteriorating effect on the character of the Exposition; nevertheless a dazzling array of pretty and tasteful objects was produced. Mr. Wyatt, speaking of that Exposition, remarks, "Evidence is exhibited on all hands of the extent to which the education of her workmen has been carried. Scarcely ever do we recognise a piece of bad ornamental modelling: where the human figure is introduced, it is rarely ignorantly drawn.

(1) "A Report on the Eleventh French Exposition of the Products of Industry. Prepared by the direction of, and submitted to the President and Council of, the Society of Arts. By Matthew Digby Wyatt, Architect." London 1849. This able Report has been of considerable assistance in the preparation of this Section.

In the departments of manufacture requiring tender manipulation, such as the more delicate articles of jewellery, carving, tooling, &c., we recognise a practised hand, acting in unison with an ever-thoughtful head. Everything seems produced, to a certain extent, *con amore;* and on conversing with every tradesman he will be found to take an immediate pride in his occupation, as a means of elevating him in the social scale, rather than as a drag to prevent his entering into competition with a class whose hopes, fears, associations, prejudices, virtues, and demerits,

Plan of the Palace of Industry, French Exposition, 1844.



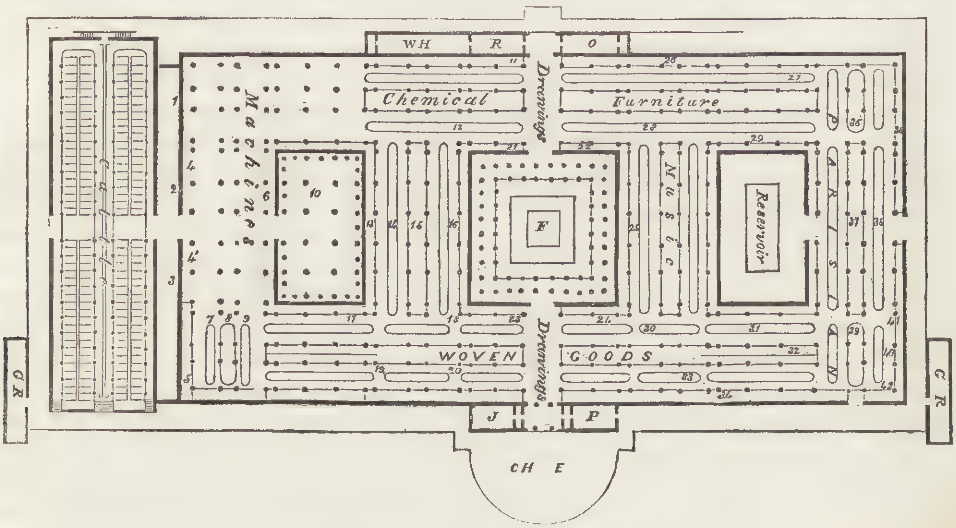
J R. Jury Room.
R A. Royal Apartments.
S. Stores.
O. Offices.
Q. Queen's Apartments.
1 1'. Lyons.
2. Lille.
3. St. Quentin.
4. Roubaix.
5. Turcoing.
6. Tarare.
7. Rheims.
8. Alençon.
9. Amiens.
10. Seine Inférieure.
11. Printed Woollen Fabrics.
12. Mulhouse.
13. Nismes.
14. Turcoing.
15. Avignon.
16. Metz.
17. Glass
13. Terra Cotta
19, 19'. Jewellery.
20, 20'. Bronze.
21. Lamps.
22, 22'. Surgical and Optical Instruments.
23. Stamped Copper.
24. Clocks.
25. Inlaid works and Tables.
26. Cabinet work.
27. Billiard Tables.
28, 28'. Pianos.
29. Books and Paper.
30. Musical Instruments.
31. Carpets.
32. India Rubber.
33. Horse-hair Fabrics.
34, 34'. Chemical Products.
35. Marble and Stucco.

have little natural affinity to his own. Thus, French manufacture has a certain peculiar charm, which frequently paralyses the judgment in appreciating the numerous structural defects which her productions constantly exhibit. If a piece of furniture be well and artistically carved, the ordinary eye cares little whether it be or be not well fitted or well seasoned. A beautiful silver-gilt ornament is at once preferred to an ugly gold one, and a paper-hanging printed in two tints which harmonize is far preferable to one executed with sixty, all of which *fight* and weary the eye. The only important branches of manufacture in which, to judge from the present Exposition, France seems decidedly behind England, are those of the application of mechanism to carving on a large scale, the manipulation of gutta percha, tin-plate and Britannia-metal working, earthenware, and japanning on papier mâché, and generally, perhaps, in her immediate adaptation of new machinery to facilitate, and consequently cheapen, production ; while in many departments, such, for instance, as the cultivation of the art of enamelling, of bronze working, of the production of artistic stone-ware, the making and colouring of terra cotta, and of riband and silk weaving, and dyeing, she appears as decidedly in advance. . . . The predominating feature of this year's Exhibition in France, is the manifestation of her *power* to get up those machines on the possession of which our facility in production has long depended, and if once she attain in this department anything approaching our mechanical resources, at the same time retaining her present artistic capability, there is little doubt that she will be enabled to

command many markets to which *we* alone *now* procure access, and which we are too apt to regard as permanent property, rather than as requiring peculiar and continued exertion to

GROUND PLAN OF THE NATIONAL EXHIBITION OF THE PRODUCTIONS OF FRENCH INDUSTRY, 1849.

Towards the river.



Towards the Great Avenue of the Champs Elysées.

C H. E. Chief Entrance.
J. Jury. P. President.
G R. Guard Room.
W H. Warehouse.
R. Refreshment. O. Office.
F. Fountain, Horticulture.
1. Carriages.
2. Sugar Refinery.
3. Stoves.
4. Morocco and Japanned Leather.
5. Looking Glasses.
6. Tin-plate Work.
7. Chimney Pieces.
8. Terra-cotta.
9. Marble.
10. Metal Works.
11. Colours and Oil Cloth.
12. Algeria, Pottery, Perfumes, Food.
13. Musical Instruments, Cutlery.
14. Flowers, Stays, Shoes, Wigs.
15. Gloves, Hats, Fur.
16. Fishing and Sporting Registers.
17. Flannel, Troyes.
18. Wool, Elbœuf.
19, 20. Cotton, Rouen, Haut Rhin.
21. Paper, Fancy ditto.
22. Composition Ornaments.
23. Rheims, Elbœuf.
24. Turcoing, Roubaix.
25. Carpets, Works of Art, Carton-pierre.
26. Beds, Paper-hangings, Bronze.
27. Various Furniture, Marquetry.
28. Typography, Sofas, Chairs.
29. Lacquered Ware.
30. Flax, Roubais.
31. Tapestry, Lace [illegible]ls.
32. Lyons.
33. Silk, Embroidery, Ribbons.
34. Rhône.
35. Glass.
36. Lustres, Clocks.
37. Watches and Chronometers.
38. Jewellery, Porcelain.
39. Weapons, Lamps.
40. Optical Instruments.
41. Painted Glass.
42. Blinds.

monopolize." In this Exposition the raw products of Algeria seemed to promise much as a field for the outlay of French energy and capital.

The following is a General Abstract of these Expositions of Industry :—

PERIODS OF OPENING.		No. of days open.	PLACE OF EXHIBITION.	Number of	
Days and Months.	Years.			Exhibitors.	Prizes.
1. Three last complementary days..	1798	3	Champ de Mars	110	23
2. Five complementary days	1801	6	Louvre	229	80
3. Idem	1802	7	Idem	540	254
4. Idem	1806	24	Esplanade des Invalides	1,422	610
5. 25th August, and following days	1819	35	Louvre	1,662	809
6. Idem	1823	50	Idem	1,642	1,091
7. 1st August	1827	62	Idem	1,795	1,254
8. 1st May	1834	60	Place de la Concorde	2,447	1,785
9. Idem	1839	60	Champs Elysées	3,281	2,305
10. Idem	1844	60	Idem	3,960	3,253
11. 4th June	1849	56	Idem	4,494	

In these Expositions the nature of the Government was as follows :—The first was under the

sanction of the Directory; Nos. 2 and 3, under the Consulate; No. 4, under the Empire; Nos. 5 and 6, under Louis XVIII.; No. 7, under Charles X.; Nos. 8, 9, and 10, under Louis Philippe; and No 11, under the Republic.

Section II.—On the Position of the United Kingdom as a Manufacturing Nation.

Such is a very brief outline of the eleven Expositions of France, and of the steady perseverance with which successive French Governments (however widely different in political views) have fostered and encouraged the manufacturing industry of the nation. In the mean time what was being done in the United Kingdom? Was the British Government engaged in similar wise and prudent measures for the encouragement of the national manufactures? We fear the answer must be, that so far from our manufactures having been encouraged by the Government, they have been impeded in a variety of ways,—by heavy taxes, and injurious Excise regulations. Since the peace of 1815 our manufacturers have been incessantly engaged in a struggle with successive Governments, for the purpose of freeing our native industry from the heavy restrictions which had been laid upon it during a long series of costly wars. It is true that, in many cases, the Government has reluctantly yielded to the earnest requests of our manufacturers, and by slow degrees some of our most important products have been loosened from the trammels of the Excise officer. But in the midst of this long contest how is it that our country has been able to maintain her manufacturing supremacy, and, notwithstanding the formidable rivalry of other nations, to be at the present moment more prosperous than at any other period of her history? In order to answer these questions, we must enter into several details, for the causes of our prosperity are somewhat complex.

If a visitor to the Great Exhibition commence his thoughtful survey of that wondrous assemblage where he ought to commence, namely, with "Section I.—Raw Materials," he will see spread out before him that which contributes in no small degree to his country's greatness. It will be obvious that if we had had to depend upon foreign nations for a supply of such heavy and bulky articles as iron, copper, tin, lead, wool, leather, flax, &c., our advance must have been slow; but having these, we have the *materials of machinery* at hand, and can apply them in a thousand different ways, which advancing science and improving experience from time to time suggest.

But the possession of these important raw materials would have been comparatively valueless but for another bounteous gift of Providence—our Coal, which is exhibited in blocks of many tons weight. Had it not been for this, our steam-engines and spinning-mules could not have had a profitable existence; but having the ores and also the means of working them in greater abundance than most other nations, we have an undoubted superiority in the production of machinery. The steam-engine is, as it were, the right hand of manufactures, and our coals are the muscles which give it strength and motion. Hence our coals have been appropriately termed "vast magazines of *power*, warehoused and ready for use." Waterfalls have now lost much of their value, except under peculiar local circumstances; for steam may be supplied with greater regularity than water, and is under command at all seasons. A number of steam-engines may be erected in the immediate vicinity of each other, so that various departments of manufacturing industry may be brought together in the same town or neighbourhood, so as to produce a combination and adaptation of employments to each other, and a consequent saving of labour. The horse-power by which steam-engines are estimated, is equal to 33,000 lbs. avoirdupois, raised 1 foot high per minute. But an animal horse-power is equal to only 22,000 lbs. raised 1 foot high per minute, or in other words, to drag a canal boat 220 feet per minute with a force of 100 lbs. Hence a steam-engine horse-power is equal in working efficiency to one living horse, and half the labour of another. But a horse cannot work more than 8 hours out of the 24, while a steam-engine needs no rest; and hence to make the animal power equal to the physical, a relay of $1\frac{1}{2}$ fresh horses must be found 3 times in the 24 hours, which amounts to $4\frac{1}{2}$ horses daily. A common 60-horse steam-engine, therefore, does the work of $4\frac{1}{2}$ times 60 horses, or of 270 horses. But suppose such an engine to be worked at a power of 120 horses by day and

60 horses by night, then such an engine does the work of 405 living horses in 24 hours. The keep of these horses at 1*s.* 2*d.* each per day, would amount to 7,500*l.* sterling in a year of 313 days. As 80lbs., or 1 bushel of coal, will produce steam equal to the power of 1 horse in a steam-engine during 8 hours' work, 60 bushels, worth about 30*s.* at Manchester, will maintain a 60-horse engine in fuel during 8 effective hours, and 200 bushels, worth about 100*s.*, during 24 hours. Hence the expense per annum is 1,565*l.* sterling, being little more than one-fifth of that of living horses. As to prime cost and superintendence, the animal power would be greatly more expensive than the steam power. Many of the engines made by Boulton & Watt continued during 40 years and upwards in constant work with very slight repairs. "What a multitude of valuable horses would have been worn out in doing the service of these machines! and what a vast quantity of grain would they have consumed! Had British industry not been aided by Watt's invention, it must have gone on at a retarding pace, in consequence of the increasing cost of motive power, and would long ere now have experienced, in the price of horses and scarcity of waterfalls, an insurmountable barrier to further advancement. Could horses, even at the low prices to which their rival, steam, has kept them, be employed to drive a cotton-mill at the present day, they would devour all the profits of the manufacturer. Steam-engines furnish the means not only of their own support, but of their multiplication. They create a vast demand for fuel; and while they lend their powerful arms to drain the pits and to raise the coals, they call into employment multitudes of miners, engineers, ship-builders, and sailors, and cause the construction of canals and railways; and while they enable these rich fields of industry to be cultivated to the utmost, they leave thousands of fine arable fields free for the production of food to man, which must have been otherwise allotted to the food of horses. Steam-engines, moreover, by the cheapness and steadiness of their action, fabricate cheap goods, and procure in their exchange a liberal supply of the necessaries and comforts of life, produced in foreign lands."[1]

The possession of raw materials, abundance of coal, and the steam-engine, have doubtless been powerful auxiliaries in the prosperity of this country; but these causes are not in themselves sufficient to account for our position as a great manufacturing nation. We owe much to our insular position, which enables us to maintain an easy intercourse with all parts of the world, so that our manufacturers can obtain the raw materials and industrial products of other countries, and give in exchange for them the produce of our own manufactures. Surrounded as we are on all sides by the sea, "the great highway of nations," we can deal with the most distant as well as with the nearest people, by the cheapest method of transit. The soil and climate of this country are also favourable to industry. Although fertile, our soil produces few articles of value without the laborious exertions of man; and our climate is sufficiently severe to stimulate us to make provision for wants which are less felt, or are even unknown, in more genial regions. Thus the difficulties of our situation call forth and stimulate our industry, and develop qualities which produce a beneficial influence on the progress of society.

Our manufacturing and commercial prosperity may also be traced to our civil and political liberty, based as it is on a free form of government, and a code of laws strong enough to vindicate the rights of the subject. Ever since the accession of the House of Hanover, a free form of government has given freedom to native industry, and has protected it by its strong arm. The manufacturer knows that the capital invested in his factory is as secure as if it had been laid out on an estate. If this had not been the case, our mines of rich ore, our coal-mines, and the advantages of our insular situation, would have been bestowed in vain; for the moment the idea came to be generally entertained that property was insecure, our career as a nation would be at an end. Ever since the celebrated Act of 1624 for the abolition of monopolies, industry, with some trifling exceptions, has been left quite free. It is true that we have not always been allowed to buy in the cheapest nor to sell in the dearest market; but the most intense competition has always existed among producers at home. While other countries on the Continent have had their industry clogged and their energies impeded by

(1) Ure: "Philosophy of Manufactures."

feudal and corporate privileges, every man in Great Britain is left to exert his energies in his own way, to adopt every fair device by which he can best attain his object, and to carry his labour and his produce to markets of his own choosing.

Some writers have even contended that the influence of taxation has been beneficial rather than otherwise in exerting a healthy stimulus to increased exertions, to meet the burden which taxation imposes; and thus a much larger amount of wealth is produced than is abstracted by the tax. The most injurious influence of taxation arises from the partial manner in which it is assessed, from its inequality, and its interference with the processes and details of industry. Much, however, has been done of late years to remove these injurious impediments, thus giving an assurance that those which still remain cannot be continued much longer.

One of the most valuable results of the free institutions of this country is religious toleration. Every man's conscience is left free, and he can adopt whatever form of worship accords with his notions of the revealed will. Hence, the religion of this country being founded on Scripture, and not on dogmas and tradition, partakes of the practical character of the people. The precept which requires the individual to be "true and just in all his dealings," has been adopted by the nation; and hence we have unbounded *credit*, the consequence of a strict maintenance of public faith, and almost illimitable *wealth*, the effect of industrial and commercial enterprise. The progress of this country since the peace of 1815 has been perfectly marvellous. We have reformed our national system of representation, given freedom to municipalities, extended the limits of religious liberty, given freedom to the press, conferred political privileges on the great bulk of the population, and, by an extensive system of cheap and healthy literature, enlarged their views, and elevated their tastes. We have increased our commerce, expanded our powers of production in manufactures, and increased our agricultural wealth. The salutary consequence of all this has been, that, the mind having been left free and independent, science has made gigantic strides, and enriched our useful arts and manufactures with most valuable discoveries. Our manufacturing towns have grown up into great cities; villages have expanded into towns; gigantic enterprises have been undertaken and completed with vigour, strength, and perfection. Canals, docks, railways, and other useful works, have been produced at an expense which must be estimated by hundreds of millions of pounds sterling. All these effects have naturally increased our power abroad, and our colonies have shared in the prosperity of the mother country; for while our colonies relieve us of the products of our manufactures, we have a constant demand on them for raw material; while they are keeping our labouring population employed, we are calling upon them for increased activity. The same remarks apply to our foreign trade generally; so true is it that all the workers and consumers of the great human family influence each other more or less directly, though separated by thousands of miles.

In estimating the prosperity of a country, it would be unfair to draw our illustrations from only one class. If the manufacturing arts are highly prosperous, the agricultural are in a state of depression. There is no doubt that at the present time the low price of corn is acting disastrously on the corn-growers of this country. Every great change in our social relations calculated to benefit the great bulk of the population must prove injurious to a class. The comparatively few suffer from the repeal of protective duties on corn, while the majority are enjoying the benefits of free trade in that prime necessity of life. The chief burdens of this country are borne by the manufacturing and operative population: it is by means of taxes directly or indirectly collected from them that we keep faith with the public creditor, and support our army and navy. The burdens on land may just now be oppressive: rents imposed during the long period of protection, and with a paper currency, cannot now be paid; but the time cannot be far distant when the farmer may find it to his interest to grow something more profitable to him than corn, and to throw into his proceedings a portion of that energy and scientific skill which has had such powerful influence in raising our manufactures to their present point of perfection. It is gratifying to observe that so large a portion of the British Section of the Great Exhibition is devoted to agricultural implements, produce, and articles connected with the pursuits and processes of rural economy. The farmer, like the manufacturer, must become

a scientific man, or like him be ready to avail himself promptly of the results which advancing science is constantly producing for the benefit of all.

One of the witnesses examined some years ago before the Hand-loom Weavers' Committee, gives in a few words a satisfactory answer to the arguments in favour of protection :—"If I make a piece of cloth, and meet a Frenchman with a sack of corn on his back, I should be glad to exchange ; but up steps a custom-house officer, and won't let me, and I may eat my cloth if I can." Now, unless Great Britain can produce a sufficient supply of corn for the whole of her immense population, which she cannot do under the best system of agriculture and at the lowest rents, or with land free from all rent, we must supersede this custom-house officer, and allow the foreigner to exchange his sack of corn for our piece of cloth.

But the prosperity of our home manufactures not only affords direct subsistence to immense numbers of individuals, but acts powerfully on the agricultural and other classes, supplying them with an infinite variety of useful and necessary articles at low prices, and creating an almost boundless market for their own peculiar products. Some dairy farmers in Cheshire informed Dr. Taylor,[1] that they had not discovered the inseparable connexion between the two interests, until the closing of a mill in their neighbourhood deprived them of all their best customers. In periods of manufacturing distress, the sale of agricultural produce, particularly milk, cheese, and butter, is greatly depressed. Nor is the influence confined within the limits of the manufacturing districts. It extends throughout the land. The herrings of Sunderland, the wools of Sussex, the butter of Cork, the malt of Hants and Essex, are standards by which to judge of the state of industry in Yorkshire and Lancashire.

The charge that has been brought against our manufacturing towns, that they are the seats of vice, turbulence, and infidelity, is no more true than that the rural districts are the abodes of virtue, peace, and simplicity. Large cities and small villages have their vices, for these belong to human nature. If the village is not disgraced by a gin-palace, it has its beer-shop. If the mill has not always been safe from the violence of refractory operatives, the rick-yard has not been secure from the midnight incendiary. In short, the vices of one system have their counterparts in those of the other. And may not their virtues be also similarly counterbalanced? There is no doubt that if large towns are bad, they would have been much worse but for factories. Factories are the best academies for poor children, for by their means they are taken out of the streets and brought up in habits of order, regularity and industry; they are regularly taught in factory schools and in Sunday-schools; their health is improved by working in spacious, well-warmed and well-ventilated mills, and their earnings have enabled their parents to feed and clothe them comfortably and respectably.[2]

Section III.—The First National Industrial Exhibition of Great Britain.

The foregoing details will not be considered an irrelevant introduction to our notice of the Great Exhibition of the Works of Industry of all Nations, of which indeed our Cyclopædia may itself be taken as the exponent. We have reason to be grateful for our commercial prosperity and the advantages which we have gained ; but as time goes on it will be more and more difficult for us to maintain our position. It does not, however, belong to the energetic character of our people to rest satisfied with present conquests, and the foreign department of our Great Exhibition will prevent us from undervaluing our rivals. The steady progress which the French have made in manufacturing industry, as shown by the details of our first section, has been shared in by other nations, as has been proved by their National Expositions. So long ago as 1836 the Baron Dupin, in referring to these expositions, glanced also at England. He said,—"The increasing brilliancy of our industrial expositions has attracted the attention of foreign states. Most of those in Europe have followed our bright example, even those which seemed the least progressive. Austria and Spain, Piedmont and Portugal, the two Sicilies and the Low Countries, Prussia and Bavaria, Holland and Denmark, Sweden and Austria, have established

(1) Tour through the Manufacturing Districts, 1842.

(2) In this section the Editor has borrowed a few paragraphs from a paper contributed by him to Mr. Weale's excellent work entitled, "London and its Vicinity Exhibited in 1851."

national expositions, the advantages of which they have fully recognised, and on this account have made them periodical. England alone, of all the states of Europe, conceives herself to be too wealthy and too superior to have recourse to such stimulants to industry. She depreciates and disdains such efforts. She apparently closes her eyes: she is nevertheless fully alive to the attempts which are now being made to diminish that inequality in the industry of nations, and consequently to cause the supremacy of one over all the others to disappear."[1]

The first national Exposition of the United Kingdom is not unworthy of our fame. Every Englishman must feel an honest pride in the beautiful Glass Palace,—itself a glorious contribution to the Exposition; the wonderful celerity with which it was completed; the large amount of capital concerned in it; the power, the energy, and the skill of those who prepared the iron, and the glass, and the timber; the judicious but incessant activity of those who put the materials together; the simple but tasteful decoration, the grand and novel effect of the whole,—all this must excite our pride and admiration; nor are these patriotic feelings at all diminished when we come to examine our contributions to the Exposition. These we shall have to speak of in due course.

It is justly remarked in the Introduction to the official descriptive and illustrated Catalogue, that "the activity of the present day chiefly develops itself in commercial industry; and it is in accordance with the spirit of the age that the nations of the world have now collected together their choicest productions. It may be said without presumption, that an event like this Exhibition could not have taken place at any earlier period, and perhaps not among any other people than ourselves. The friendly confidence reposed by other nations in our institutions; the perfect security for property; the commercial freedom and the facility of transport which England preeminently possesses, may all be brought forward as causes which have operated in establishing the Exhibition in London. Great Britain offers a hospitable invitation to all the nations of the world, to collect and display the choicest fruits of their industry in her capital; and the invitation is freely accepted by every civilized people, because the interest both of the guest and host is felt to be reciprocal."

The great success which had attended the French Exposition of 1844, caused several representations to be made to the British Government, respecting the benefit which a similar exhibition would be likely to confer on the industry of the United Kingdom; but as no hopes were held out that the Government would undertake any pecuniary liabilities in establishing a national exhibition, it became evident in the course of the various negotiations, that such an exhibition, if established, must be self-supporting. Indeed the success which has attended this Exhibition may in great measure be attributed to the fact that it was originated, conducted, and completed without any assistance whatever from Government except its sanction, the provision of a site for the building, the organization of police, foreign correspondence, &c., and in all cases where any expense has been incurred, it has been defrayed from the funds of the Exhibition.

In June 1845 the Society of Arts attempted, by means of a Committee of Members, to carry out a scheme for an Exhibition of National Industry; and an inquiry was made among manufacturers as to how far they would contribute their support. Nothing, however, was done in the matter until the year 1847, when the Council of the Society established an Exhibition on a small scale, intended to be the first of a series. In 1848 the experiment was repeated with increased success, whereupon the Council announced their intention of holding an annual Exhibition, with the view to establish a quinquennial Exhibition of the Works of British Industry, to commence in 1851. The Council also attempted to connect the Schools of Design of the great manufacturing districts with the proposed Exhibitions, and obtained the promised cooperation of the Board of Trade; they also secured the promise of a site from the Chief Commissioner of Woods and Forests, who offered the central area of Somerset House, or some other Government ground. In the year 1849 the Exhibition was still more successful, and some of the objects exhibited were contributed by Her Majesty. To assist in carrying out the

(1) " Rapport du Jury Central sur les produits de l'industrie Française exposés en 1834 " Par le Baron Charles Dupin. 3 vols. 8vo. Paris, 1836.

intention of holding a National Exhibition in 1851, the Council of the Society caused the Report on the French Expositions, from which we have already quoted, to be prepared. A petition was also presented to the House of Commons, praying that the use of some public building might be granted for the purposes of the Exhibition of 1851. This petition was referred to the Select Committee on the School of Design.

About this time, however, His Royal Highness the Prince Albert, as President of the Society, took the matter under his own personal superintendence, and proceeded to settle the general principles on which the proposed Exhibition should be conducted, and to consider the mode in which it should be carried out. His Royal Highness expressed his views on the subject, in a speech made on the occasion of a banquet given by the Lord Mayor of London to the municipal authorities of the United Kingdom, for the purpose of promoting the Exhibition. His Royal Highness said :—"Gentlemen, I conceive it to be the duty of every educated person closely to watch and study the time in which he lives, and, as far as in him lies, to add his humble mite of individual exertion to further the accomplishment of what he believes Providence to have ordained. Nobody, however, who has paid any attention to the particular features of our present era, will doubt for a moment that we are living at a period of most wonderful transition, which tends rapidly to the accomplishment of that great end to which, indeed, all history points—the realization of the unity of mankind ;—not a unity which breaks down the limits and levels the peculiar characteristics of the different nations of the earth, but rather a unity the result and product of those very national varieties and antagonistic qualities. The distances which separated the different nations and parts of the globe are gradually vanishing before the achievements of modern invention, and we can traverse them with incredible ease; the languages of all nations are known, and their acquirements placed within the reach of everybody; thought is communicated with the rapidity and even by the power of lightning. On the other hand, the great principle of division of labour, which may be called the moving power of civilization, is being extended to all branches of science, industry, and art. Whilst formerly the greatest mental energies strove at universal knowledge, and that knowledge was confined to the few ; now, they are directed to specialties, and in these again even to the minutest points; but the knowledge acquired becomes at once the property of the community at large. Whilst formerly discovery was wrapped in secresy, the publicity of the present day causes that no sooner is a discovery or invention made, than it is already improved upon and surpassed by competing efforts. The products of all quarters of the globe are placed at our disposal, and we have only to choose which is the best and cheapest for our purposes, and the powers of production are entrusted to the stimulus of competition and capital. So man is approaching a more complete fulfilment of that great and sacred mission which he has to perform in this world. His reason being created after the image of God, he has to use it to discover the laws by which the Almighty governs his creation, and, by making these laws his standard of action, to conquer nature to his use—himself a divine instrument. Science discovers these laws of power, motion, and transformation; Industry applies them to the raw matter which the earth yields us in abundance, but which becomes valuable only by knowledge; Art teaches us the immutable laws of beauty and symmetry, and gives to our productions forms in accordance with them. Gentlemen, the Exhibition of 1851 is to give us a true test and a living picture of the point of development at which the whole of mankind has arrived in this great task, and a new starting-point from which all nations will be able to direct their future exertions. I confidently hope that the first impression which the view of this vast collection will produce upon the spectator will be that of deep thankfulness to the Almighty for the blessings which He has bestowed upon us already here below; and the second, the conviction that they can only be realized in proportion to the help which we are prepared to render to each other,—therefore, only by peace, love, and ready assistance, not only between individuals, but between the nations of the earth."

On the 30th June, 1849, a meeting of several members of the Society of Arts was held at Buckingham Palace, when His Royal Highness Prince Albert communicated his views respecting the formation of a great collection of works of industry and art in London, in 1851.

His Royal Highness considered that such a collection and exhibition should consist of the following divisions :—Raw Materials ; Machinery and Mechanical Inventions ; Manufactures ; Sculpture, and Plastic Art generally. It was a question whether this exhibition should be limited to British industry. "It was considered that, whilst it appears an error to fix any limitation to the productions of machinery, science, and taste, which are of no country, but belong as a whole to the civilized world, particular advantage to British industry might be derived from placing it in fair competition with that of other nations. It was further settled that, by offering very large premiums in money, sufficient inducement would be held out to the various manufacturers to produce works which, although they might not form a manufacture profitable in the general market, would, by the effort necessary for their accomplishment, permanently raise the powers of production, and improve the character of the manufacture itself."

At a meeting held at Osborne, on the 14th July, when the subject of an Executive Committee was discussed, it was urged by three members of the Society of Arts that one of the requisite conditions for the acquirement of public confidence was, that the body to be appointed for the exercise of the executive functions should have a sufficiently elevated position in the eyes of the public, and should be removed sufficiently high above the interests, and remote from the liability of being influenced by the feelings, of competitors, to place beyond all possibility any accusation of partiality or undue influence ; and that no less elevated tribunal than one appointed by the Crown, and presided over by His Royal Highness, would have that standing and weight in the country, and give that guarantee for impartiality, that would command the utmost exertions of all the most eminent manufacturers at home, and particularly abroad. Moreover, that the most decided mark of national sanction must be given to this undertaking, in order to give it the confidence, not only of classes of our own countrymen, but also of foreigners accustomed to the expositions of their own countries, which are conducted and supported exclusively by their governments. It was also stated, that under such a sanction, and with plans properly prepared, responsible parties could be found ready to place at the disposal of the Commission sufficient funds to cover all preliminary expenses and the risks incidental to so great an undertaking. Whereupon it was determined that a Royal Commission should be applied for, and that the Society of Arts should organize the means of raising funds, and collect evidence as to the readiness of the great manufacturing and commercial interests to subscribe to and support the undertaking.

In proceeding to act upon these suggestions the Council of the Society of Arts felt that the proposal for such an Exhibition must not be referred to as conditional, but as an event which had already been decided on. The Society, however, had no funds of their own to make the necessary advances towards a building, but after much negotiation with several builders and contractors, an agreement was made between the Society of Arts and Messrs. Munday, by which the latter undertook to deposit 20,000*l.* as a prize fund, to erect a suitable building, to find offices, to advance the money required for all preliminary expenses, and to take the whole risk of loss on certain conditions. The receipts arising from the Exhibition were to be dealt with as follows :—the 20,000*l.* prize fund, the cost of the building, and 5 per cent. on all advances, were to be repaid in the first instance : the residue was then to be applied in various ways : a certain sum was to be paid to the Society of Arts as a fund for future Exhibitions ; a certain sum would be required for incidental costs, such as those for general management, preliminary expenses, &c. ; whilst a certain sum, to be agreed upon by arbitration, was to be the remuneration of the contractors for their outlay, trouble, and risk. But, in thus making a contract with private parties for a national object, it was prudently foreseen that if the public identified itself with the Exhibition, they would prefer not to be indebted to private enterprise and capital for carrying it out ; a provision was accordingly made with the contractors, by which it was agreed that if the Treasury were willing to take the place of the contractors and pay the liabilities incurred, the Society of Arts should have the power of determining the contract before the 1st February, 1850, in which case the compensation to be paid to Messrs. Munday was to be settled by arbitration.

In the autumn of 1849, several members of the Society of Arts visited the most important cities and towns of the United Kingdom, for the purpose of collecting the opinions of the leading manufacturers on the subject of the Great Exhibition. It appeared from the Reports of the Visitors, that in 65 places public meetings had been held, and Local Committees of Assistance formed, and that nearly 5,000 influential persons had registered themselves as promoters of the proposed Exhibition.

These Reports being presented to Her Majesty's Government, the Queen was pleased to issue her Royal Commission, which was published in the "London Gazette" of 3d January, 1850. At the first meeting of the Royal Commissioners, held on the 11th January, it was felt that the experiment about to be tried was of a national character, and ought to rest for its support upon national sympathies, and upon such liberal contributions as those sympathies might dictate; it was, therefore, resolved to terminate the contract with Messrs. Munday, and thus throw the whole burden of the Exhibition upon voluntary contributions, the Commissioners taking upon themselves, individually and personally, the whole responsibility of the undertaking, both pecuniary and executive. The Society of Arts, accordingly, gave the requisite notices to Messrs. Munday, and in due time all the outlay which they had made, amounting to about 23,000*l.*, with interest, was repaid to them.

In the mean time subscriptions continued to be received; they were transferred to the general fund at the Bank of England, in the names of the Treasurers named in the Royal Commission. The gross amount of subscriptions was 75,000*l.*, which, after deducting expenses of local committees, collection, printing, &c., realized 64,000*l.* The general financial position of the undertaking at the opening of the Exhibition on the 1st May, 1851, was as follows:—

Receipts.		Expenditure and Liabilities.	
Subscriptions paid to April 22, 1851	£64,344	Building	£79,800
For privilege to print the Catalogues	3,200	Extra galleries, counters, and their fittings, estimated at	35,000
For privilege to sell Refreshments	5,500	By Prize Fund	20,000
By Season Tickets to April 29	40,000	Management, including printing and all incidental expenses incurred up to April	20,940
Admissions of the public		Management during the Exhibition	
Royalty on sale of the shilling Catalogue			

As the United Kingdom had *invited* other countries to join the Exhibition, the greatest care was taken to discourage the receipt of any subscription from any foreigner, resident at home or abroad.

At a time when the actual receipts were only 35,000*l.* it was necessary to make positive arrangements for the erection of the building, and the President and every member of the Royal Commission were legally responsible in respect of every pecuniary engagement. To relieve them from this position the Commissioners were formed into a Corporation, by Charter, 15th August, 1850, and a guarantee fund of 230,000*l.* was formed by a limited number of persons, one of whom opened the list with a subscription of 50,000*l.* Upon the security of this fund the Bank of England agreed to make such pecuniary advances as should from time to time be required.

The fundamental principles upon which the Exhibition would be held were formally announced in February 1850, so that there was a full year for preparations. The 1st May, 1851, was fixed for opening the Exhibition; a site for the building had been granted by Her Majesty on the south side of Hyde Park, lying between the Kensington Drive and the ride called Rotten Row. The exhibitors would be required to deliver their objects at their own cost and risk at the building, but no rent would be charged to them for exhibition. The Commissioners reserved to themselves full power of control respecting the admission of British articles; but with respect to Foreign articles, the power of admitting them was confided absolutely to an authority of the country which sent them; such authority to be appointed or recognised by the Government of each particular country, the Commissioners recognising no other, and holding no communication with private and unauthorized persons.

In order to give foreign countries as long a time as possible for their preparations, the Commissioners resolved to divide a certain amount of space, amounting to about 213,000 super-

ficial feet,[1] among foreign countries for the purposes of the Exhibition. A space equal to upwards of 51,000 square feet was also divided among the British Colonies. Foreign and Colonial productions were to be admitted for the purposes of the Exhibition free of duty, the building being considered as a bonded warehouse.

With respect to the demand for space by British exhibitors, all persons were invited to transmit a general description of the nature of each article, and the space required for it, to the Secretary of the nearest Local Committee, and this Committee was required to digest the returns so made to them, and transmit them to the Commissioners before the 31st October, 1850. Upwards of 330 Local Committees were formed in the three parts of the United Kingdom and the Channel Islands. The whole of the demands for floor and counter space thus made, exceeded 417,000 superficial feet, being in excess of the amount of available space for the United Kingdom by about 210,000 superficial feet. The number of exhibitors was upwards of 8,200. In adjusting these claims, the Commissioners, as a general rule, allotted to each Local Committee an amount of space in each section, in proportion to the number of exhibitors which had been returned by each Committee. Each individual application for space was then transmitted to the respective Local Committees, for revision and correction, which, when returned by the Committees, was considered as the voucher for the admission of the articles.

Such is a very brief outline of the proceedings of the Commissioners in organizing the Exhibition of 1851. There is one feature about it which deserves to be brought out into prominent view, because it illustrates so admirably the character of the British people and of their institutions, viz. the self-supporting and self-acting principle of this Exhibition. The continental Exhibitions are managed and paid for wholly by their Governments; and the same remark may be applied, in a large number of cases, to their roads and railroads, their bridges, canals, docks, harbours, and all similar works: the people for the most part remain quiet or simply obey orders, while the Government does the work and provides the means. In Great Britain, on the contrary, the people manage their own affairs either by municipal and corporate bodies, or by private companies, who obtain the authority of the legislature for carrying out some gigantic work, the cost of which is defrayed by private capital, raised among numerous shareholders. This state of things may be regarded both as the effect and the cause of our national freedom and independence, leading to the happiest results. The expenses of our first national exhibition having been defrayed by the direct spontaneous contributions of all classes—the shilling of the poor man, and the pound of the rich—is a much better subject of national pride and congratulation, than if a sum of money had been voted by Parliament, and paid officers appointed to carry out the scheme. Nor is our pride diminished when we know that all parties concerned in this great and useful undertaking have been willing to make sacrifices of time, of money, of property, or of all three; from the poor man who subscribed his shilling, to the Prince Consort who has devoted his time, his talents, and the influence of his high position. The Commissioners who have undertaken such severe labour, such heavy responsibilities, are all unpaid; the Local Committees throughout the United Kingdom, without whose assistance an Exhibition of this kind must have been impossible in this country, are also unpaid. All have been working towards the attainment of one common end, and that end has been attained with a success, a completeness, and a grandeur, which have excited the admiration and the gratitude of all.

Section IV.—Proposals for the Building.

In January 1850, the Commissioners appointed a Committee "for all matters relating to the building," consisting of the Duke of Buccleuch, the Earl of Ellesmere, Messrs. Barry, Cubitt, Stephenson, Cockerell, Brunel, and Donaldson. On the 21st February 1850, they reported favourably on the fitness of the proposed site in Hyde Park, and recommended that upwards of sixteen acres should be covered in; that it was desirable to obtain suggestions by public competition as to the general arrangements of the ground-plan of the building; that when such a plan had been obtained and approved, to invite builders, &c. to furnish designs, accompanied

(1) This is rather more than the entire space occupied by France for its two Expositions of 1844, and 1849.

by tenders for the construction of the building in the form, and according to the general arrangement, which should be fixed upon. In answer to the invitation to send in plans, upwards of 245 designs and specifications were submitted. Of these 38 were contributed by foreigners, (France sending 27,) 128 by residents in London and its environs; 51 by residents in the provincial towns of England; 6 by residents in Scotland; 3 by residents in Ireland, and 7 were anonymous. All these plans were publicly exhibited in London during a month; and the Building Committee in reporting on their merits selected two lists of competitors, one of which they considered to be entitled to "favourable and honourable mention," and the other, to "further higher honorary distinction." They stated, however, that they did not consider any single plan to be "so accordant with the peculiar objects in view, either in principle or detail of its arrangement, as to warrant them in recommending it for adoption." The Committee, therefore, submitted a plan of their own for a brick building, in which the principal points of excellence endeavoured to be attained, were economy of construction; facilities for the reception, classification, and display of goods, as also for the circulation of visitors; arrangements for grand points of view; centralization of supervision; and lastly, some striking feature, to exemplify the present state of the science of construction in this country. This last object was proposed to be attained by a dome, 200 feet in diameter, formed of wrought-iron ribs supporting a covering of corrugated iron, resting on a drum of brick-work 60 feet high: the cupola was to rise to a height of more than 160 feet: such a dome would exceed the span of that of St. Peter's at Rome by 61 feet, and that of St. Paul's, London, by 88 feet. Working drawings were prepared and lithographed, and invitations for tenders issued. Public opinion, however, was opposed to the erection of such a building on such a site: it was thought that so massive a structure was not required for so temporary an object, and that being once erected it would not be removed at the close of the Exhibition; and even supposing such a building to be necessary, it ought to be on some other site, as the carting of the materials and the presence of so vast a multitude of workmen, would inflict a permanent injury on the park and its neighbourhood. The subject was even brought before the House of Commons, and the question raised as to whether the proposed site should be used at all for the purposes of the Exhibition. On two occasions, a large majority voted in the affirmative.

In inviting professional men to send in tenders, the Commissioners did not insist upon the details of their lithographic sketches being strictly adhered to: on the contrary, they wished to avail themselves "of the accumulated and experimental knowledge and resources of intelligent and enterprising contractors;" and they requested to be furnished with "such suggestions and modifications, accompanied with estimates of cost, as might possibly become the means of effecting a considerable reduction upon the general expense."

Nineteen tenders were sent in, but eight only were for undertaking the whole of the work: the amounts ranged between 150,000*l.* and 120,000*l.*, and this for the use only of the materials for the building. In accordance, however, with the invitation of the Commissioners just referred to, Messrs. Fox, Henderson & Co. presented a tender for a structure composed chiefly of glass and iron, adapted in form to the official ground-plan. The design for this structure was by Mr. Joseph Paxton, who had been induced to submit it chiefly in consequence of the opposition which had been raised to the official building. In making their report on these tenders, the Commissioners proposed to omit the great dome, and some portions of the design which did not appear to be essential, by which they supposed its cost might be reduced below 100,000*l.*: they also made special mention of Mr. Paxton's design, which, however, they thought would prove more expensive.

In the meantime, however, Mr. Paxton published his design and a description thereof, in the *Illustrated London News* of the 6th July, 1850, and the effect on the public mind was immediately favourable. Murmurs of disapprobation were changed into expressions of applause; it was seen at once that such a structure was capable of being erected within a reasonable time, and taken to pieces and removed with ease and celerity, when it had accomplished its destiny. This induced the Commissioners fully to investigate the subject, and finally to adopt, on the

26th July, Messrs. Fox & Henderson's tender, to construct Mr. Paxton's building as then proposed, for the sum of 79,800*l*. Considerable modifications, additions, and improvements, were subsequently made in the details, which have added considerably to this sum; but the merit of the design in most of its essential features belongs to Mr. Paxton: the constructive skill, the energy and promptitude which have been so eminently displayed, belong to Messrs. Fox & Henderson, and the parties immediately connected with them, in supplying the materials within so short a period, especially Messrs. Cochrane and Mr. Jobson, who supplied the iron, and Messrs. Chance, of Birmingham, who furnished the glass.

The history of Mr. Paxton's design furnishes an interesting illustration of progress, not only in the mind of the inventor, but also in the manufacturing arts, which contributed the materials. In a lecture delivered by Mr. Paxton at the Society of Arts, on the 13th November, 1850, we have the inventor's own account of the design, from which it appears that the peculiar construction of the building in cast-iron and glass, together with the manner of forming the vast roof, were the result of much experience in the erection of buildings of a similar kind, although on a smaller scale. In 1828, when Mr. Paxton first directed his attention to the improvement of glass structures, the various forcing-houses at Chatsworth and elsewhere were formed of coarse thick glass and heavy woodwork, which rendered the roofs dark and gloomy, and not well adapted to their intended purposes. The evil was remedied by bevelling off the sides of the rafters and sash-bars. A light sash-bar was also contrived, containing a groove for the reception of the glass, thereby obviating an objection to the old mode of glazing, by which the putty was displaced by the action of the weather, and the wet, finding its way between the glass and the wood, produced a continual drip in rainy weather. Metal sashes and rafters, instead of wooden ones, had been proposed for horticultural purposes; but the expansion and contraction of the metal always prevented such roofs from being tight: moreover, the expense was increased at least fourfold.

In the construction of glass-houses requiring much light, the following objection appeared. In plain lean-to or shed roofs, the morning and evening sun, which is on many accounts of great importance in forcing fruits, presents its direct rays at a low angle, and consequently, very obliquely to the glass. At those periods, most of the rays are obstructed by the position of the glass, and of the heavy rafters, as shown in Fig. III., and much of the benefit arising from the

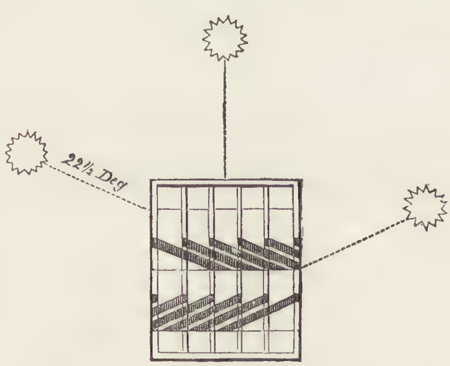


Fig III. THE OLD MODE OF GLAZING.

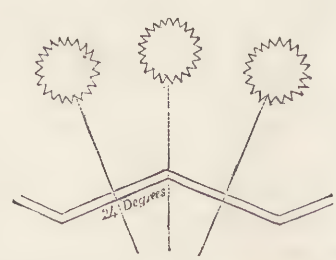


Fig. IV. THE RIDGE-AND-FURROW ROOF.

influence of the morning and evening sun is thus lost. It occurred to Mr. Paxton that this objection might be obviated by placing the glass more at right angles to the morning and evening rays. This led to the adoption of the ridge-and-furrow principle for glass roofs, Fig. IV., which places the glass in such a position that the morning and evening rays enter the house without obstruction, and present themselves more perpendicularly to the glass at those times when they are the least powerful; whereas, at mid-day, when they are most powerful, they present themselves more obliquely to the glass.

In applying this principle, a still lighter sash-bar than any previously used was employed; and in 1836, when it was determined to erect the great conservatory at Chatsworth, it was

desirable to contrive some means for abridging the great amount of manual labour required in making the immense number of sash-bars requisite for the purpose. On visiting the great workshops of London, Manchester, and Birmingham, the only apparatus which Mr. Paxton met with was a grooving machine : this was fitted up at Chatsworth in connexion with a steam-engine, and subsequently so improved as to make the sash-bar complete. This machine produced a saving of 1,400*l.* in the expenses of the conservatory. The length of each of the bars was 48 inches, only one inch shorter than those of the Exhibition Building. The original cost of this machine, including table, wheels, &c. complete, was 20*l.* The motive power was a steam-engine employed on the premises for other purposes, and any well-seasoned timber could be used. The attendants required were only a man and a boy. The sash-bars could be made of any form by changing the character of the saws. The bar was presented to the saws below the centre of motion, and to the teeth of the saw which were ascending from the table. A velocity of 1,200 revolutions per minute was required to finish the work in a proper manner.[1]

With respect to the glazing of the Chatsworth conservatory, Mr. Paxton very properly desired to do away with the numerous overlaps connected with the old system of glazing with short lengths. Messrs. Chance & Co., of Birmingham, had about this time introduced from the Continent the manufacture of sheet-glass, which they were able to make in lengths of three feet : Mr. Paxton was advised to use this glass in two lengths, with one overlap ; but this he would not assent to, because, as the manufacturers had so far advanced as to be able to produce sheets three feet in length, he saw no reason why they could not accomplish another foot ; and if this could not be done, he would decline giving the order, as at that time *sheet*-glass for horticultural purposes was altogether an experiment. The manufacturers accepted the order on the conditions imposed ; and they have since produced glass for the Exhibition 49 inches long,—a size which no country but England is able to furnish in any large quantity, even at the present day.

It is not necessary to describe the buildings erected by Mr. Paxton for horticultural purposes, in which the ridge-and-furrow roofs were successfully introduced. It did not occur to him that a building of cast-iron and glass, with this form of roof, might be adapted to the Great Exhibition, until he had seen the numerous objections which had been urged against a large structure of bricks and mortar in Hyde Park. But the time for sending in the designs had expired. What was to be done ? Mr. Paxton submitted his plan to Messrs. Fox & Henderson, who were about to send in tenders for the gigantic building of brick, with its colossal dome. As those who sent in tenders for this building were allowed to make suggestions, provided such suggestions were accompanied by detailed plans and estimates, Messrs. Fox & Henderson, seeing at a glance that the Paxton design was the one most suitable for the intended purpose, at once recommended it to the notice of the Royal Commissioners, and undertook to prepare detailed plans of such design, together with estimates, in the short space of one week. The difficulties of such an undertaking as this may to a certain extent be appreciated, when it is considered that before an approximate estimate of the cost of such a building could be formed, the great glass-manufacturers and iron-masters of the north had to be consulted. These gentlemen were summoned to the office of Messrs. Fox & Henderson, to contribute their several estimates to the tender for the whole. Nevertheless, within the stipulated week the contractors had prepared detailed although not working drawings, and had calculated the cost of every pound of iron, of every inch of wood, and of every pane of glass.

" There is no circumstance in the history of the manufacturing enterprise of the English nation which places in so strong a light as this its boundless resources in materials, to say nothing of the arithmetical skill in computing at what cost and in how short a time those materials could be converted to a special purpose. What was done in those few days ? Two parties in London, relying on the accuracy and good faith of certain iron-masters and glass-workers in the provinces, and of one master carpenter in London, bound themselves for a certain sum of money, and in the course of some four months, to cover 18 acres of ground with

(1) A drawing and description of the more complete machine used in making the sash-bars for the Great Exhibition building will be given in Section VI.

a building upwards of a third of a mile long, and some 450 feet broad. In order to do this, the glass-maker promised to supply in the required time 900,000 square feet of glass (weighing more than 400 tons), in separate panes, and these the largest that ever were made of sheet-glass; each being 49 inches long. The iron-master passed his word in like manner to cast in due time 3,300 iron columns, varying from 14½ feet to 20 feet in length; 34 miles of guttering tube, to join every individual column together under the ground; 2,224 girders (but some of these are of wrought-iron); besides 1,128 bearers for supporting galleries. The carpenter undertook to get ready within the specified period 205 miles of sash-bar; flooring for an area of 772,784 square feet, exclusive of galleries; besides enormous quantities of wooden walling, louvre-work, and partition.[1] It is not till we reflect on the vast sums of money involved in transactions of this magnitude, that we can form even a slight notion of the great, almost ruinous, loss a trifling arithmetical error would have occasioned, and of the boundless confidence the parties must have had in their resources and in the correctness of their computations. Nevertheless, it was one great merit in Mr. Paxton's original details of measurement, that they were contrived to facilitate execution. There was little time for consideration, or for setting right a single mistake, were it ever so disastrous. On the prescribed day the tender was presented, with whatever imperfections it might have had, duly and irredeemably sealed. But after-checkings have divulged no material error."

Mr. Paxton states that the design for the building involved various considerations, and was therefore planned, *first*, with especial reference to the object in view, viz. the Exhibition of 1851; *secondly*, its suitableness for the site proposed to be occupied by the structure; and *lastly*, with a view to its permanence as a winter garden, or vast horticultural structure, or a building which might, if required, be used again for a similar exhibition. One great feature in the building is that no stone, brick, or mortar was required; but the whole is composed of dry material, so that as the parts were put together, the enclosed space was ready for immediate use.

We cannot better conclude this Section than by quoting from the speech of Mr. Fox, at Derby, on the 21st June, 1851, on the occasion of a public dinner given to him by his fellow-townsmen. He said:—

"Before entering on a brief history of the building, I wish to state, that it is to Mr. Paxton's idea of a palace of iron and glass, which it has been my lot to mature and realize, that the public are indebted for the present structure in Hyde Park; and that gentleman proudly acknowledges that but for the enlightened views of the Duke of Devonshire, the Lord Lieutenant of this county, and his Grace's princely expenditure at Chatsworth, the idea of such a building might never have been entertained. In June, 1850, the Royal Commission invited contractors to tender for a building to be erected in Hyde Park, in conformity with plans and specifications prepared by the Building Committee. The building, which was intended to consist principally of brick and iron, with a splendid dome in its centre, was considered of too permanent a nature for subsequent removal, and public opinion to this effect was very generally expressed. In the printed condition of tender issued by the Building Committee the following clause was introduced:—'Tenders for methods of construction other than those shown upon the drawings and described in the specifications, will be entertained, but on condition only of their being accompanied by working drawings and specifications, and fully priced bills of quantities.' This invitation to parties to send in tenders, based not only on the Committee's plans, but upon such other designs as they might wish to submit, induced me to believe that a tender for a building of glass and iron, as suggested to me for the first time by Mr. Paxton, on the 22d of June, 1850, just twelve months ago, an engraving of which was published in the *Illustrated London News* on the 6th of July, would meet not only with the approbation of the Building Committee, but with that of the public at large; and I therefore went to Birmingham on the 28th of June, and put in hand the drawings and specifications upon which our tender to the Committee was to be based. On the 2d of July Mr. Cole, having heard of our intention to make an offer for a building of the kind, and feeling strongly that the success of the Exhibition depended upon having an attractive and suitable building, came down to Birmingham at his own suggestion, but with the permission of competent authority, to stimulate us to proceed, and to offer such hints in reference to the requirements of the case as would enable us to make the conception of Mr. Paxton conform strictly to the condition of tender required by the Commissioners, and therefore most likely to meet with the approbation of the Building Committee; and I am of opinion, that to his spirited advice we are mainly indebted for obtaining an impregnable *locus standi* on the merits of our case. In all this I had the co-operation of my partner Mr. Henderson, who, feeling with me the value of Mr. Cole's suggestions, and the great importance, in the preparation of these drawings, of conforming as much as possible to the arrangements adopted by the Committee in the plan upon which they had invited tenders, proposed the addition of the transept, in the

(1) This passage is quoted from an article in *Household Words.* It should, however, be noticed that the estimates are not quite correct.

propriety of which Mr. Paxton, after due consideration, entirely concurred. Before completing our tender, and with a view to a more precise appreciation of the magnitude of a building covering 18 acres—1,850 feet long, 408 feet wide, and 64 feet high, irrespective of the arched roof of the transept —I walked out one evening into Portland Place; and there setting off the 1,850 feet upon the pavement, found it the same length within a few yards; and then, considering that the building would be three times the width of that fine street, and the nave as high as the houses on either side, I had presented to my mind a pretty good idea of what we were about to undertake, and I confess that I considered the difficulties to be surmounted in constructing that great palace were of no ordinary kind; but feeling confident that with great energy, good arrangements, and a hearty co-operation on the part of our extensive and well-disciplined staff, it might be accomplished, and that upon it depended in all probability the success of the Exhibition, we determined to undertake the responsibility; and the opening on the 1st of May has proved the correctness of our conclusions. The plans and specifications prepared by us in great haste were submitted to the Commissioners, together with a tender, on the 10th of July; but though sufficient to enable us to bring the subject before them, and to convey to their minds an idea of what we proposed to erect, they were necessarily very incomplete, and did not contain either sufficient architectural or mechanical detail to admit of their being used in the execution of the works. The arched roof was afterwards added to the design, and submitted to the Commissioners on the 15th of July, with the view of getting over a difficulty which existed in consequence of the elm-trees being too tall to be covered by the flat roof proposed by Mr. Paxton. For the expense attending the addition of the arched roof to the transept, Fox, Henderson & Co. did not increase the amount of their former tender, and it was consequently executed at their sole expense. The Building Committee, having had the matter under their consideration from the 15th to the 26th of July, resolved unanimously to recommend the Commissioners to accept our offer for the building, and nothing could be more disinterested than their conduct in setting aside the drawings and specifications which, with much labour, they had prepared, and adopting others, which, though laid before them in so imperfect a state, presented to their minds, as experienced engineers and architects, the mode of constructing a building of iron and glass better fitted for the purposes of the Exhibition. On the recommendation of the Building Committee the Commissioners, on the 26th of July, were pleased to signify their wish for us to construct the building, but were met by a difficulty which threatened to postpone for a year, if not to put an end to the Exhibition altogether. The Solicitor to the Treasury gave as his opinion, that until the Commissioners had obtained a Royal Charter they could not legally proceed, and were therefore not in a position to give an order to any one. These circumstances were explained to us by Lord Granville on the 26th of July, in the presence of the Commissioners, who at the same time told us that it was their fixed intention to apply to Government for the Charter, and that he had every reason to believe it would be granted; and having informed us that as soon as they were a legally constituted body they would probably conclude a contract with Fox, Henderson & Co., finished by asking whether under these circumstances we should consider it running too great a risk to enter at once upon the execution of the work, as otherwise many weeks would unavoidably be lost, and the chance of opening the Exhibition on the 1st of May placed beyond possibility. In reply to his Lordship's inquiry, seeing the imperative necessity for immediate action, and desiring to render all the assistance in our power in furtherance of the important objects of the Exhibition, we expressed our willingness to run the risk, whatever it might be; and without waiting for the Charter, commenced at once the drawings and the necessary operations for the erection of the building. As the time for the execution of the building was so extremely limited, and being well aware from experience that when matters of business had to be decided by a committee composed of many persons much valuable time was generally wasted, we requested the Commissioners, instead of referring us to the Building Committee, to select one of its members—either the Chairman, Mr. Cubitt, President of the Institution of Civil Engineers, Mr. Robert Stephenson, or Mr. Brunel—and give him absolute power to settle with us finally all matters connected with the arduous task we were then willing to enter upon. The Commissioners, appreciating the importance of this request, appointed Mr. Cubitt to fill this office. It was now that I commenced the laborious work of deciding upon the proportions and strengths required in every part of this great and novel structure, so as to ensure that perfect safety essential in a building destined to receive millions of human beings—one so entirely without precedent, and where mistakes might have led to the most serious disasters. Having satisfied myself on these necessary points, I set to work and made every important drawing of the building, as it now stands, with my own hand, and it was no small source of gratification to me, when asking Mr. Cubitt to look over the drawings I had prepared, to find that he not only had no desire to suggest alterations, but expressed his entire approbation of them all. The Commissioners having carefully considered the merits of the various sites proposed for the Exhibition, among which may be named Leicester Square, Somerset House, Trafalgar Square, the Isle of Dogs, Battersea Fields, and Regent's Park, selected, after the most careful consideration, a portion of Hyde Park, situate between the Serpentine River and the Queen's Drive, and gave us possession of the ground on the 30th of July, when we proceeded to take the necessary levels and surveys, and to set out with great precision the position of the various parts of the building. The drawings occupied me about eighteen hours each day for seven weeks, and as they went from my hand Mr. Henderson immediately prepared the iron-work and other materials required in the construction of the building. As the drawings proceeded the calculations of strength were made, and as soon as a number of the important parts were prepared, such as the cast-iron girders and wrought-iron trusses, we invited Mr. Cubitt to pay a visit to our works at Birmingham to witness a set of experiments in proof of the correctness of these calculations. We first placed upon each part the greatest load it could ever in practice receive, and proceeded to show that above four times that load was required before fracture would occur. These proofs were made on the 6th of September, when Mr. Cubitt was pleased to state that he never witnessed a set of experiments of a more conclusive nature. Being thus satisfied by actual experiment that the proportions of the various parts of the building were such as to ensure perfect stability and safety, the preparations of the iron-work and other materials was pushed forward with the greatest vigour, and large deliveries were made

in the Park within the next three weeks; so that on the 26th of September we were enabled to fix the first column in its place.

"From this time I took the general management of the building under my charge, and spent all my time upon the works—feeling that, unless the same person who had made the drawings was always present to assign to each part as it arrived upon the ground its proper position in the structure, it would be impossible to finish the building in time to ensure the opening on the 1st of May; and I am confident that if any other course had been taken, or if, as is usual in the construction of large buildings, the drawings had been prepared by an architect, and the works executed by a contractor, instead of, as in the present case, these separate functions being combined by my making the drawings and then superintending the execution of the work, a building of such vast dimensions could not have been completed within a period considered by experienced persons as altogether inadequate for the purpose. The erection of the building, now fairly commenced, was pushed forward with all possible speed, and a good notion of the amount of work may be obtained from the fact, that at one period we fixed as much iron-work every day as would be required in a roof of extent equal to the passenger station of this town, which is one of the largest in the kingdom. It was not until the 31st of October that the contract with the Commissioners was completed, up to which time we not only had received no order for the building and no payment on account of the work we had done, but we had run the risk of expending upwards of 50,000*l.* without being in a legal position to call upon the Commissioners for any portion of the sum we had so expended; and such was the appreciation of our conduct in this matter, that Lord Granville was pleased, in the presence of the other members of the Commission, to state, on the 16th of November, that they were of opinion that but for the courage evinced by Fox, Henderson & Co., in commencing the work without any order from the Commissioners, the Exhibition of Industry of all Nations would never have taken place. Perhaps the most difficult and hazardous, and certainly the most interesting portion of the work, was raising the 16 ribs of the transept to their places. A month was the shortest time assigned by any one for this operation. We commenced on the 4th of December, and succeeded in raising two in the course of that day. Two more were safely deposited in their places, in the presence of his Royal Highness Prince Albert, on the following day, and the last pair on December 12; so that the 16 ribs were all placed in eight working days. As the building progressed I was assailed on all sides, not only by unprofessional persons, but by men of high scientific attainments, who, notwithstanding the careful calculations which had been made, and the satisfactory proofs to which all the important parts were individually subjected, as soon as these parts were put together and produced a structure of unparalleled lightness, doubted the possibility of the building possessing, as a whole, that strength which was necessary to make it safe against the many trying influences to which it must necessarily be subjected. When the Royal Commissioners confided to us the construction of the building for the Exhibition of Industry of all Nations, I felt that in some degree the credit of England was in our hands; that we had it in our power to achieve that which would prove eminently successful, or in failing to do so would be a source of the most serious disappointment and disgrace; and that we were, therefore, bound by considerations of no ordinary kind to exert every effort in our power to carry the work to completion in the shortest possible time, and at any personal sacrifice, and without regarding the question of expense; the more especially as his Royal Highness Prince Albert had invited the world to this great festival on the 1st of May; and it was essential, as a point of national honour, that this vast edifice should be ready for the reception of his guests. I need not remind you that we completed the contracts, and that our beloved Sovereign presided at the inauguration on the day which had been originally appointed. I feel a peculiar pleasure in having carried out this great undertaking, in the consideration that it is not a temple in which the representatives of nations will meet together for the purpose of adjusting matters of strife or questions of warfare, but one in which the Prince has invited all the family of man to assemble in harmony and good fellowship, and where juries, composed of distinguished foreigners and Englishmen, meet together as friends, to decide upon the comparative merits of those beautiful objects of art and manufactures which are the happy results of peaceful commercial emulation."

Section V.—General Description of the Building.

It may be necessary to give a short, general description of the building, before we enter upon the details of its construction. Such of our readers as have visited the Great Exhibition will peruse this and the next Section with an increased degree of interest; and those who have not had that privilege, may, we trust, from the following account, gain a tolerably accurate idea of the most remarkable structure of the present age, and be able to appreciate the means by which it was so rapidly brought into existence. The novelty of the structure and the many ingenious mechanical contrivances brought to bear upon it, will sufficiently warrant a somewhat minute description. Whatever may be the fate of this building, it is tolerably certain that any other that may hereafter be erected for a similar purpose will not surpass it in interest. This building is *the* building of *the* Great Exhibition of 1851. The Exhibition of 1856 may be more magnificently housed, and may surpass this one in splendour and general effect, but nothing that may hereafter be produced will lessen the pride and pleasure with which we may exclaim in after years:—"I visited the Great Exhibition of 1851, and saw the good Queen Victoria walking in the midst of thousands of her subjects, with no other protection than their loyalty and love!"

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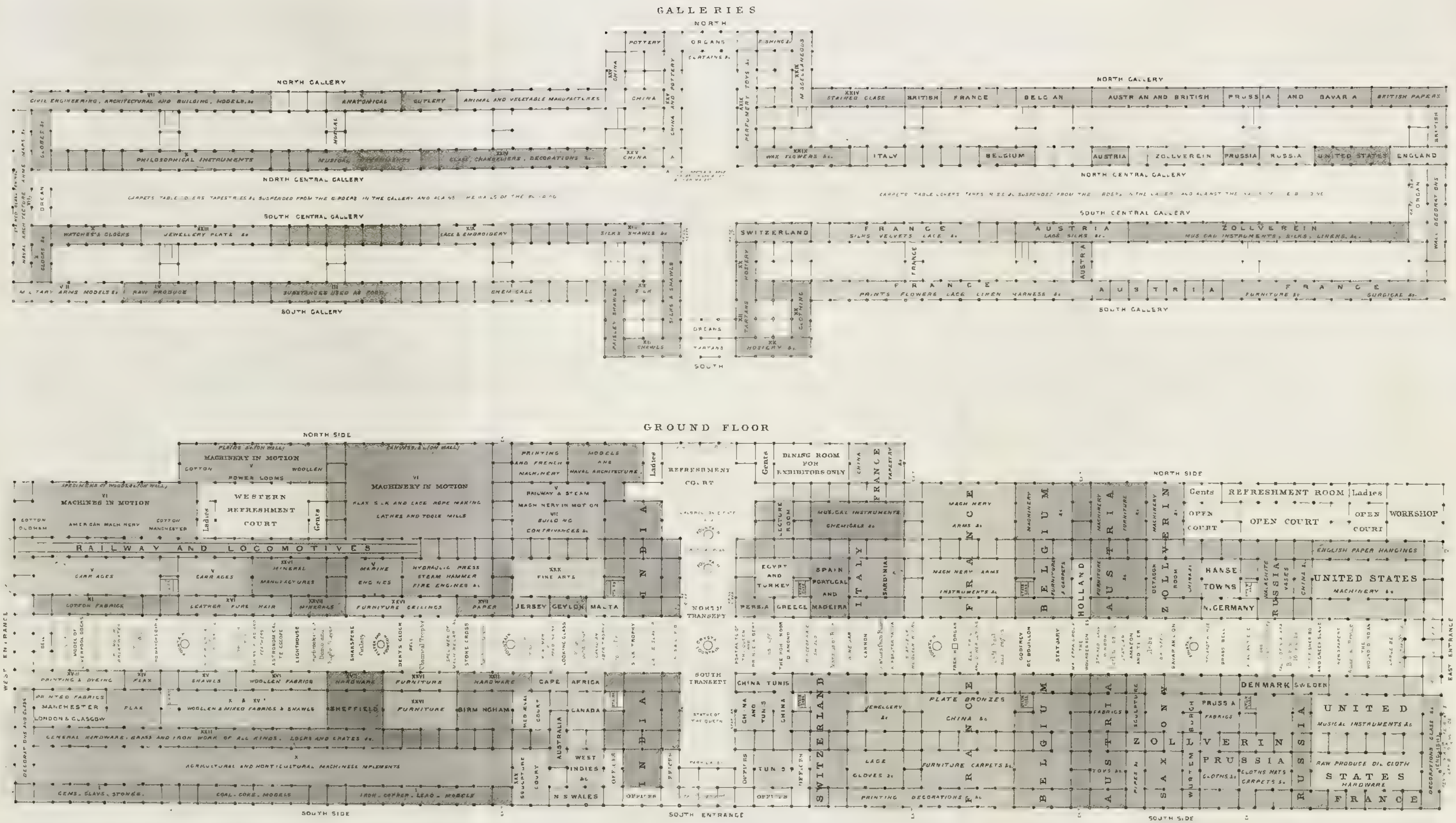


PLAN OF THE BUILDING ERECTED FOR THE GREAT EXHIBITION 185

The site for the building is a rectangular slip of ground in Hyde Park, situated between the Queen's Drive and Rotten Row, and containing about 26 acres, its length being 2,300 feet, and its breadth 500 feet. The principal frontage extends from east to west. Several lofty elms stretch across the centre of its length, and a few smaller trees are scattered over its area. The well-known and laudable attachment of the people to their parks, and to the fine old trees which adorn them, made it desirable to retain at least the finest of them, and to this circumstance we are indebted for the beautiful transept roof which encloses them. The position of the smaller groups of trees led to the formation of open courts near the refreshment rooms, which have been found singularly refreshing to the numerous family groups who visit the Exhibition for a whole day, and carry their provisions with them. These open courts contain fountains, and *jets d'eau*, and are surrounded with tables and seats under a canopy.

It was not to be expected in a site of such vast extent that the ground would be perfectly level. Accordingly, there was found to be a fall of 1 in 250 from west to east, or a difference of level of about 8 feet between the two extreme ends occupied by the building. In order to prevent the necessity of having a flight of steps at one end of the building to compensate for this difference in level, it was determined to arrange the floor with an inclination nearly following that of the ground, such fall being at the rate of 1 inch in 24 feet; to make all the horizontal lines of the building follow this line of the floor, and to make the vertical lines at right angles to the floor, or slightly to incline from the perpendicular towards the east. This deviation is so small, as not to be perceptible to the eye. (See Fig. VI.)

The general appearance of the building, both externally and internally, is shown in the steel engravings which accompany this essay; the engraved plan both of the ground floor and of the gallery floor will also be found useful. The chief entrance to the building is in the centre of the south side, opposite to the Prince of Wales's Gate, from which a good view is obtained of the southern façade of the transept. (See Fig. V.) Passing through a vestibule 72 feet by 48,[1]

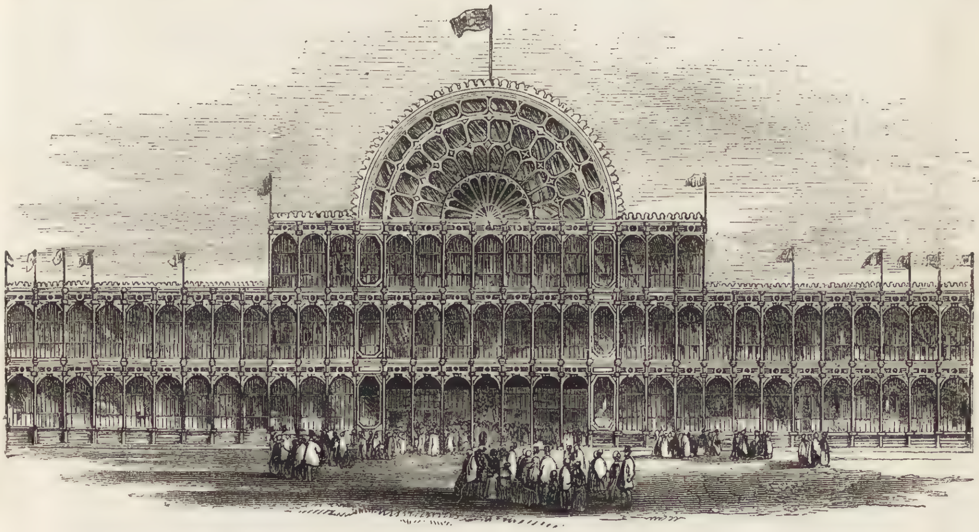


Fig. V. SOUTHERN FAÇADE OF THE TRANSEPT.

we gain admittance to the building, and advancing about half-way along the transept, we arrive at what may be called the centre of the building, which is marked by a beautiful glass fountain. From this central point the effect is marvellous, and can scarcely be occupied without a thrilling sensation of admiration and delight: we fully appreciate the feeling which led to the remark of a lady, a friend of the Editor,—"My first impulse was, to sit down and weep." Perhaps the

(1) In designing the building, the horizontal measure of 24 feet has been taken as the unit; so that every horizontal dimension is a certain number of times or divisions of 24 feet. Thus, the position of every column in the building is at the points of intersection of lines 24 feet apart, crossing at right angles; while in roofing and flooring, the squares into which the whole plan has thus been divided are subdivided into other squares of 8 feet.

first thing that strikes the eye from this point is the absence of walls and solid partitions, and in their stead a multitude of *lines*, symmetrically grouped, and falling harmoniously into their places: then, the eye, not taking in at a glance, but, as it were, travelling along one of the vast naves on either side of the transept, surveys the aërial perspective of the horizontal girders which support the transparent roof, marks how the light blue with which they have been, by a wise judgment, painted, combines the several girders into a tender sky-blue tint, most refreshing to the sight, tempered as the light is by the canvass covering to the roof, and contrasting with the bright effect of the noble transept, whose vast circular transparent roof admits the sunshine, lights up the crystal fountain at which we are standing, illumines the trees and the flowers, brings into bold relief the various and varied groups of statuary, and adds new beauty to the beautiful world of marble. The mind is long in becoming accustomed to the scene, for the intellect is appealed to most powerfully through several of the senses: the eye is dazzled by innumerable forms artistically grouped, and rich in variety of colour; the ear is flooded with the swelling harmonies of the organ, subdued in an extraordinary manner by the vastness of the place, or is detained for a moment by the pleasant sound of moving waters, or the still more pleasant hum of gratified visitors. This last effect is, indeed, not the least exciting part of the Exhibition: a moving mass of human beings, men, women, and children, sometimes amounting in one day to upwards of 70,000 in number, subdued by the beautiful, interested by the useful, refined and instructed, brought into closer communion with their species, and forgetting the rivalries of nations in the friendly contest of the fine arts and the industrial arts, are practically taught to sympathise with all the members of the great human family.

The nave, which we thus survey on either side of the transept, is the main avenue of the building: it is 72 feet wide, and 64 feet high. On either side of the nave, and parallel therewith, are aisles, or smaller avenues, 24 feet in width; and above them, at a height of 24 feet from the ground, are carried galleries, which surround the whole of the nave and the transept, so that, at that level, a complete circuit of communication is carried throughout the whole structure. Beyond and parallel with these first aisles, at a distance of 48 feet, are second aisles, of similar width, also covered with galleries on the same level as those over the first aisles. The two galleries are connected by cross galleries, or bridges, at frequent intervals, which span the 48-feet avenues, and divide them into courts, each of which, being complete in itself, is an interesting object as viewed from the galleries. Ten double staircases, 8 feet wide, are so placed between the lines of galleries as to give access to either. Two additional staircases of smaller size have been erected in the eastern half of the building, and in the western half is a beautiful specimen of staircase, placed by an exhibitor, and in constant use for reaching the galleries. The 48-feet avenues and the second aisles are roofed over at a height of 44 feet from the ground. The remaining width of the building consists of a projection on the north side, 48 feet wide, and 936 feet long. It is roofed at a height of 24 feet, and has no galleries. A reference to the separate engraving of the ground-plan and to the vertical section, Fig. VI., will give a clear idea of the skilful manner in which this vast area has been distributed.

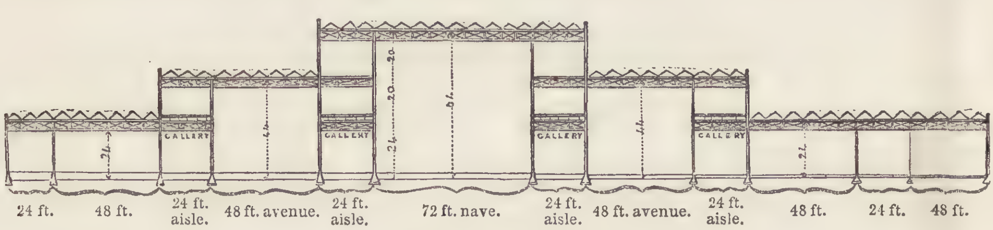


Fig. VI. VERTICAL SECTION.

The avenues into which the plan has been divided are formed by hollow cast-iron columns, 8 inches in diameter: they are placed 24 feet apart, and rise in one, two, or three storeys, for the purpose of supporting the roof at different heights. In the lower storey these columns are 18 feet $5\frac{1}{2}$ inches high, and in the two upper storeys 16 feet $7\frac{1}{4}$ inches. The different lengths

of columns are united by connecting-pieces 3 feet long, so contrived as to support in horizontal tiers iron girders or trusses, thereby dividing the greatest height of the building into three storeys. Some of the girders are of cast and others of wrought-iron : they are for the most part of the same depth as the connecting-pieces, viz. 3 feet, and form a kind of lattice-work of great strength and of light and elegant appearance. The first or lower tier of girders forms a support for the floor of the galleries : the upper tier of girders supports the roof. The general form of the roof is flat, and it is made up of a series of ridges and furrows, the rise and fall of which is small. The roof is arranged in the following manner : the roof girders, being 24 feet apart, and lying transverse, or across the length of the building, the space between them is spanned by light beams or rafters, known by the name of *Paxton gutters*, from the circumstance of their being hollowed out in a groove on the top and on each side, to serve the purpose of gutters. These rafters are 8 feet apart, and their ends, which rest on the roof girders, lie in the direction of the length of the building. Between these rafters are the *ridges*, which are supported by light sash-bars sloping up to them at an inclination of $2\frac{1}{2}$ to 1, and the rafter forms the bottom of the furrow. The rain-water which falls on this roof flows into the Paxton gutter, from which it is discharged into the main gutter resting on the roof girders, whence it is conducted into the hollow cast-iron vertical columns, and passes down through them into the drain-pipes beneath the floor of the building. Hence the greatest horizontal distance which the rain-water has to travel after falling upon the roof is 48 feet; but the greater portion of the rain has to travel a much less distance before it enters the discharge-pipe. The roof covering is of glass, in sheets 49 inches long, 10 inches wide, and $\frac{1}{16}$th inch thick : it is fixed between sash-bars grooved to receive it; and in order to carry off the moisture condensed upon the inner surface, a small groove is formed on either side of the rafter, into which the moisture trickles and is then discharged into the main gutter.

The outer enclosure on the ground floor is formed by dividing each 24-feet bay between two columns into three 8-feet bays, by means of half-columns of wood, between which is placed a boarding held together by iron clips and bolts. The plinth immediately above the floor is made high, for the purpose of admitting air; this space being filled with frames containing louvre-blades hung on pivots. Similar ventilating frames, 3 feet deep, are introduced at the top of each storey all round the building. Externally some light arches are inserted, and open panels form the enclosure for the upper louvre-frames. Fig. VII., which represents a bay of the building 8 feet wide, will give a correct idea of the external construction. At intervals along the north and south sides are exit doors, each of which occupies one of the 8-feet bays, each opening being about 6 feet wide. In the upper storeys, glazed sashes are substituted for the close boarding, and the plinth is omitted. Each storey is crowned with a cornice and a cresting ornament on the outside, and posts, with flagstaffs, are carried up over the columns.

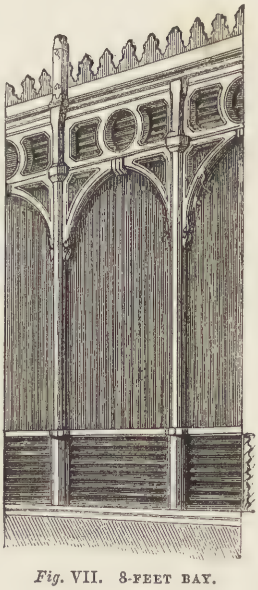


Fig. VII. 8-FEET BAY.

The floor of the interior is boarded : on the ground an interval of half-an-inch is left between the boards, to allow the dust to pass through; but in the galleries iron tongues are inserted between the boards, to prevent such an effect.

The roof of the transept is semicircular, and rises above the rest of the building : the whole of the semicylinder is seen from the outside. This roof is supported by arched timber ribs, 24 feet apart, or one over every column. Each of the columns at this part of the building forms a socket, into which each foot of the rib is fitted and secured by iron straps. Between these ribs timbers are fixed, carrying smaller ribs at the distance of 8 feet apart, upon which the ridge-and-furrow roofing is constructed, as in the flat roofing, but following the curve of the arched ribs. At the springing or foot of this arch, on either side of the transept, are louvre-frames, for ventilation : on the top of the arch on the outside is a narrow passage, which affords

access to the different parts of this roof: on the inner side of the arch are diagonal tie-rods, which tie all the parts together, and form a pleasing kind of network over the whole surface. The ends of the transept are closed in with a fan-like tracery. On either side of the arched roof is a lead flat, 24 feet wide, the only continuous portion of solid non-transparent roofing in the whole structure. Its introduction was suggested by the want of a platform for carrying on the works of the arched roof, and also for giving access to the other roofs on either side. It has also the additional value of giving increased strength to the springing of the arched ribs, thus helping to resist any tendency to spread outwards. The increased weight of this lead covering, compared with the usual glass one, made it necessary to introduce stronger roof-girders than in other parts: and there are two such on either side of the transept, at the wide span of the main avenue. The inner girder on each side also sustains two of the large arched ribs, with the roofing. These girders are of wrought-iron, 6 feet deep, the diagonal ties of which form a kind of lattice-work similar to the others.

The offices for the Executive Committee, the Electric Telegraph, &c., are situated on either side of the principal entrance: they are arranged in two storeys under the gallery, which is continued uninterruptedly over them. At the east and west ends of the building, by which the public is also admitted, there are offices of less extent. On the outside of the building at these two ends considerable spaces have been enclosed, for the purpose of exhibiting large objects which, from their weight or dimensions, could not be well accommodated within the building. The refreshment rooms are in the left wing of the building, on the north side of the main avenue, close to the open courts already noticed: the north end of the transept is also used for refreshment stalls. On the north-east side lecture-rooms have been provided, in which some eminent scientific men have delivered courses of lectures on subjects connected with the great objects for which the Exhibition was instituted.

At about 155 feet from the north-west angle of the building is the boiler house, a fire-proof structure, 96 feet by 24, resembling in external appearance the one-storey portion of the building. It contains five boilers, each supplying steam for 20-horse power, and the steam is distributed by means of pipes to the different machines in motion, situated in the north-west flank of the building. The boiler house also contains a large tank, which serves as a balance head to the water supply. This supply consists of a 6-inch main surrounding the building, and upon it, at intervals of about 240 feet, are placed fire-cocks; while at different points of its circuit sixteen 4-inch pipes enter the building, and lead so far into the interior that fire-cocks placed upon their ends are so situated that circles of 120 feet radius drawn from each of them would intersect one another. The mains running on the north and south sides of the building are connected across the transept by a 5-inch main, from which, near the centre of the building, pipes diverge for supplying the different fountains situated upon the central line of the nave.

Fig. VIII. OUTER RAILING.

The whole building is enclosed by a cast-iron railing, designed by Mr. Owen Jones: it is placed at a distance of 8 feet from the north and south sides, but is carried much further off at the ends, as already noticed. The admission into the building is on the south side (*Fig.* V.) and at the east and west ends; but as in a building liable to be so much crowded, it is desirable to afford great facility of exit, 17 exit doors have been provided; 6 along the south side, 4 along the north side, 4 at the west end, and 3 at the east end.

Such is a general sketch of this wonderful building, which for grandeur and beauty of effect attained by such simple means is, probably, unequalled. Such, too, is the simplicity of its construction, that the accommodation afforded by it can readily be extended or contracted according to circumstances. In the next Section we will trace the successive steps by which so great a result was attained in so short a time.

Section VI.—The Construction of the Building.

On the 30th July, 1850, the contractors obtained possession of the site from the Commissioners of Woods and Forests.

The first proceeding was to enclose the whole area, together with an additional space at each end, with a hoarding about 8 feet high. The boards used for the purpose were afterwards employed for the flooring of the building, and to prevent their being disfigured by nails, they were supported by pieces of timber, afterwards used as joists, fixed in the ground in pairs, at intervals of the length of the boards, leaving a narrow space between them, into which the boards were dropped. Temporary offices were erected, as also carpenters' shops, and stables for 20 or 30 horses employed upon the works. The general outline of the building, and all the points where columns would stand were then accurately set out. This was done by determining the 4 extreme angles of the building and the centre lines of the main avenues, which formed fixed points from which were determined the whole of the centres for the columns. The unit of horizontal measurement, viz. 24 feet, which occurs throughout the building, either in multiples or submultiples, was secured by measuring rods made of well-seasoned American pine, into which, within a few inches of each end, were fitted gun-metal cheeks or small projecting plates, the inner edges of which were set at exactly 24 feet apart; so that by laying one pole upon another, the inner edges of the cheeks of two separate poles were brought into contact. The length of the rods was determined by the Astronomical Society's Standard, which was referred to in the measurements for the castings, and other parts of the building. This precaution was necessary, since from the vast extent of the structure, a small error in any of the parts would have been so much multiplied as to become sensible at the ends. The measuring rods were carried along the centre lines of the columns, and the position of each column was marked by a small stake driven into the ground, and the centre was accurately fixed by a long nail driven into the head of the stake. The level for the floor was determined by the ordinary method of levelling; and stakes, with a T piece at the top, called *boning-sticks*, were fixed in different parts of the building, by the aid of which the tops of the base pieces for the columns were afterwards fixed in one plane of the required slope.

The base plates for the columns were fixed on concrete, contained in holes excavated for the purpose. But in making these holes the stakes which marked the centres of the columns had to be removed, and in order to find those centres again, a large, wooden, right-angled triangle, or carpenter's square, was used in the following manner:—at the two ends of the right-angled triangle saw-cuts were made, and before the removal of the stake, the apex of the triangle was set to the nail which indicated the situation of the centre of the column: two other stakes were then driven into the ground beneath the saw-cuts, and two nails were driven in at the ends of the saw-cuts. The wooden triangle being next removed, the centre stake was withdrawn, the hole excavated, and the concrete thrown in. The height of the surface of the mortar, varying, as it did, with almost every column, on account of the ground not being level, was regulated by pegs driven in to the correct level. In order to fix the base-plates over the centres determined for the columns, another carpenter's square was used, the right-angled corner of which was cut out to the form of the section of the upright portion of the base-piece, which was the same as that of a column. This square being placed with the notches in its short sides over the two stakes already noticed, the upright portion of the base-piece was fitted into the notch at the angle, and thus its correct position was found. To determine the level of the top of the base-pieces, boning sticks were placed in the lines of the columns, and when the base-piece had been approximately fixed, a piece of wood was placed on it edgeways, the top of which was made to range with the top of the boning sticks; the base-piece being driven down with a wooden mallet until the desired level was obtained. Each base-piece was fixed truly upright in one direction, and slightly inclined in the other by means of plumb rules, on one of which the deviation from the perpendicular line was marked, and this being applied to those faces of the base-pieces which were to incline, served to show when the proper inclination had been attained,

while the other plumb rule, applied to the upright faces, showed when they were truly vertical. Great care was required in fixing the base-pieces; for as three stories of columns were in some places to be fixed over them, any inaccuracy in their level or position would be very much increased at the top of the building.

The base-plate is shown in Fig. IX. The lower part consists of a horizontal plate, attached to which is a vertical tube of the same form as the column which it serves to carry. The connexion of the plate with this tube is strengthened by shoulders. The base-plates are set with their length north and south; and at right angles thereto, in such of the columns as serve as drain pipes, are two sockets, into which cast-iron pipes 6 inches in diameter are fixed, for conveying the rain water into drains of large size situated in the centre and at the east end of the building, which in their turn convey the water to the main sewer in the Kensington Road; the natural slope of the ground giving a sufficient fall to the pipes. At the upper portion of the tube of the base-plate are four snags, or projections with holes in them, corresponding with those at the foot of the column. The upper face of the tube and the under face of the column were all turned in a lathe so as to fit precisely without any packing; bolts were then dropped through the holes in both, and were secured by nuts. It was only in those columns that served as water pipes that any packing was introduced, and in them a piece of canvas smeared with white lead was put into the joint.

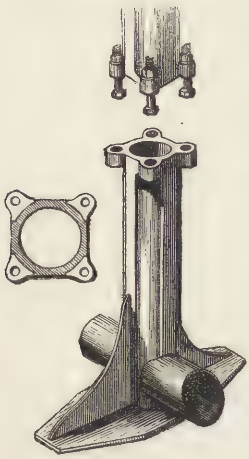


Fig. IX.

The form of the column, which was suggested by Mr. Barry, is that of a ring, 8 inches in diameter, with four flat faces, about 3 inches wide, cast upon it on the outside. The thickness of the columns varies, according to the weight intended to be supported, from $\frac{5}{8}$ of an inch to $1\frac{1}{8}$ inch. These flat bands afford surfaces well suited for attaching the horizontal girders which support the galleries and the roof, and by adding to the sectional area of the metal, greatly increase the strength of the column.[1]

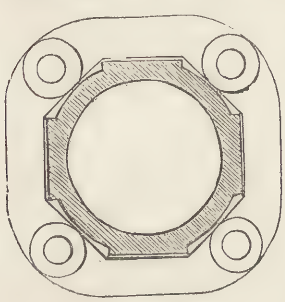


Fig. X.

Those portions of the height of the columns which correspond in depth and position with the girders, form separate lengths or *connecting pieces*, and unite the lengths of columns of the different stories. The connecting pieces are of the same sectional form as the columns, and like them have projections at each end, which serve to support the girders, and are provided with holes, through which are passed the bolts which secure them firmly to the columns. These holes alternate with projections so formed as to clip others which are cast on to the ends of the girders, and in the centre of each projection is a small notch which receives an iron key or wedge, and prevents the two surfaces from sliding upon one another. These arrangements will be explained more minutely hereafter.

Fig. XI.

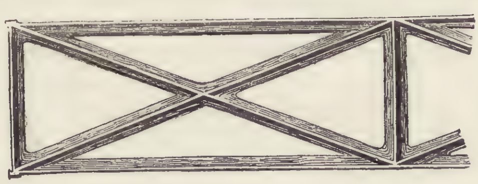


Fig. XII.

The cast-iron girders, attached to these connecting pieces, serve to support the gallery floor. These girders are all 24 feet long, and 3 feet deep, and the upper and lower flanges or tables have a ⊤-formed sectional area; the section A, Fig. XI, being 5.31 inches, and B, 7.64 inches. The rectangular space between them is divided into three equal parts by uprights having a + form of section, and the three rectangular spaces thus obtained are filled in with diagonal struts in each direction. The girder thus forms a double truss, in

(1) In a Lecture on the construction of the building, delivered on the spot by Professor Cowper, of King's College, London, 31 December, 1850, a striking experiment was shown to illustrate the great strength of a hollow tube. Two pieces of quill, each one inch long, were placed in a vertical position between two boards, the upper one being adjustable by hinges: weights were then placed on the upper board just above the quills, until they reached 224 lbs., which was found to be the crushing weight.

which the diagonal braces are subject both to compression and tension. At the top and bottom of the end standards are small projections, as already noticed, by which the connecting pieces hold the girders, and at each end of the flat portion of the top and bottom rails are small sinkings, by which the girder is keyed up to its position. The flat portions of the upper and lower flanges of the girder are swelled out in width from the ends towards the centre, to increase the weight of metal in that part where the strain is greatest. In those parts of the building where no gallery was to be supported, the girders were cast with a less weight of metal, but the form was the same.

The first column was erected on the 26th September. The different castings were carried on with steady perseverance, and were sent from Dudley to the works as fast as they were executed. Every casting as it arrived was carefully examined, weighed, registered, and covered with a coat of paint, and every girder was proved by means of a hydraulic press. For this purpose, each girder was swung by means of a crane into a very strong cast-iron frame, rather longer than the girder, the bottom of which was formed by two fixed beams, placed 8 inches apart, and supported a few inches above the ground. At each end of these a cast-iron standard was firmly bolted between them, and rose to a height rather greater than the depth of the girder to be tested: on the inner faces of these standards two shoulders were formed, which received the projections cast on the ends of the girder. Between the fixed beams below, at two points dividing the whole length into three equal parts, were placed two 3-inch cylinders with rising pistons connected with a forcing pump by a strong metal tube. A girder being placed in this frame in an inverted position, the force-pump was worked until the pistons underneath the girder carried it off its lower bearings, and pressed it upwards against the shoulders by which it was firmly held, and the pressure was then continued until a strain equal to 15 tons was produced upon the girder, or twice the weight which it would have to sustain when fixed.[1] In this way the testing strain was made upon each girder, precisely at those points and in the same manner as the load from the gallery or the roof would do when the girder was in its appointed place. A self-adjusting apparatus, attached to the hydraulic press, indicated when the test strain of 15 tons had been applied. This apparatus consisted of an iron cylinder $1\frac{1}{2}$ inch diameter, communicating with the pipe which connected the pump and the press; so that the pressure obtained in it was, in proportion to its diameter, the same as that in the large cylinder; and it was fitted with a piston rod working in a vertical direction. Attached to this piston-rod was a lever, from the end of which a scale-pan was suspended, at a distance from the fulcrum ten times greater than that of the point of attachment of the piston from the same. The weight of the scale-pan and lever were balanced by a large mass of iron at the other end. A weight was placed in the scale-pan proportioned to the proof required;[2] and the pump was worked until the water rising in the iron cylinder forced up the lever, and with it the weight attached, thereby indicating that the pressure had been attained.

Near the proving apparatus was erected one of Mr. Henderson's patent Derrick cranes, by which instrument every girder was raised from the wagon in which it arrived, placed on the weighing machine, weighed, removed to the proving press, tested, raised again and placed on the ground in a stack in less than four minutes. This crane consists of an upright mast E, Fig. XIV., kept steady when in use by two sloping stays FF, Fig. XVI. These stays are fixed in horizontal timbers on the ground, connected with the foundation plate H on which the mast turns. At the foot of the mast is a combination of wheels and handles for raising the weight, technically called a *crab*. A beam A, called the *derrick*, working at the bottom in a socket B, Fig. XVII., fixed to the foot of the mast, but hanging out from it in a sloping direction, is the chief peculiarity of the crane: it can be raised more to the upright line or lowered to slope more outwards by means of the chain C. By this contrivance a weight may be raised from or deposited at any point

(1) In one case, the pressure was continued beyond the proof weight of 15 tons, in order to see what amount of strain the girders would bear without fracture: it was found that a strain of 30 tons produced no injurious effect; but the girder broke with the additional weight of half a ton.

(2) This weight was thus determined:—the diameter of the lever cylinder being $1\frac{1}{2}$ inch, and that of each of those in the proving frame 3 inches, the rams in the latter presented 8 times the surface of that in the lever cylinder; which being multiplied by the difference of length of the two parts of the lever, determined the weight for the scale-pan to be $\frac{1}{80}$th of that to which it was desired to prove the girder.

Fig. XIII. FRAME AND HYDRAULIC PRESS FOR PROVING THE GIRDERS.

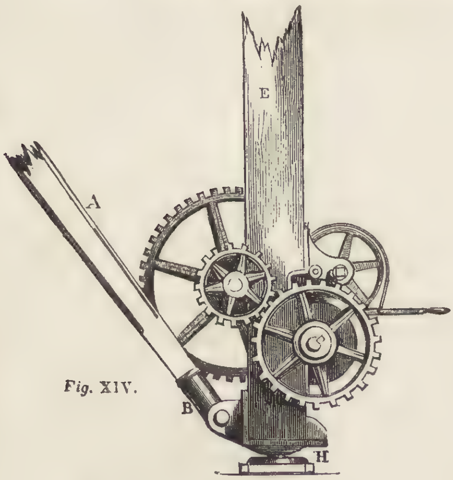


Fig. XIV.

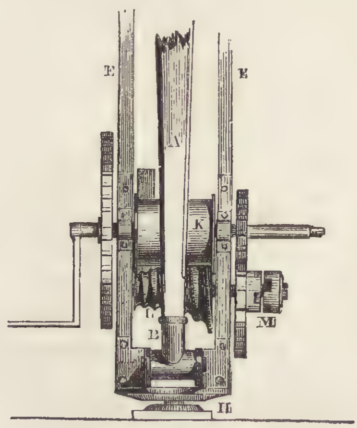


Fig. XV.

within a circle of a radius depending on the length of the derrick; while in the ordinary crane the weight can only be placed at points upon the circumference of that circle. The whole engine revolves on a pivot, at the foot of the mast. Cranes of this description vary in power from 1 to 40 tons, and with derricks ranging from 20 to 60 feet radius.

Persons who visited the works during the erection of the building were struck with the absence of scaffold-

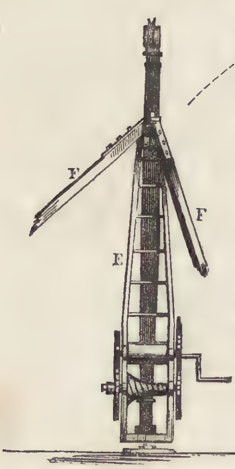


Fig. XVI.

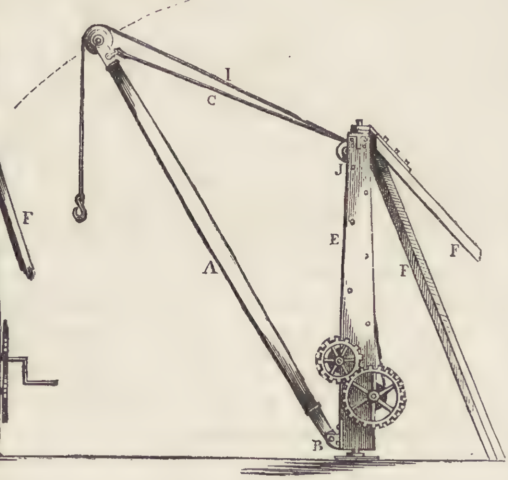


Fig XVII.

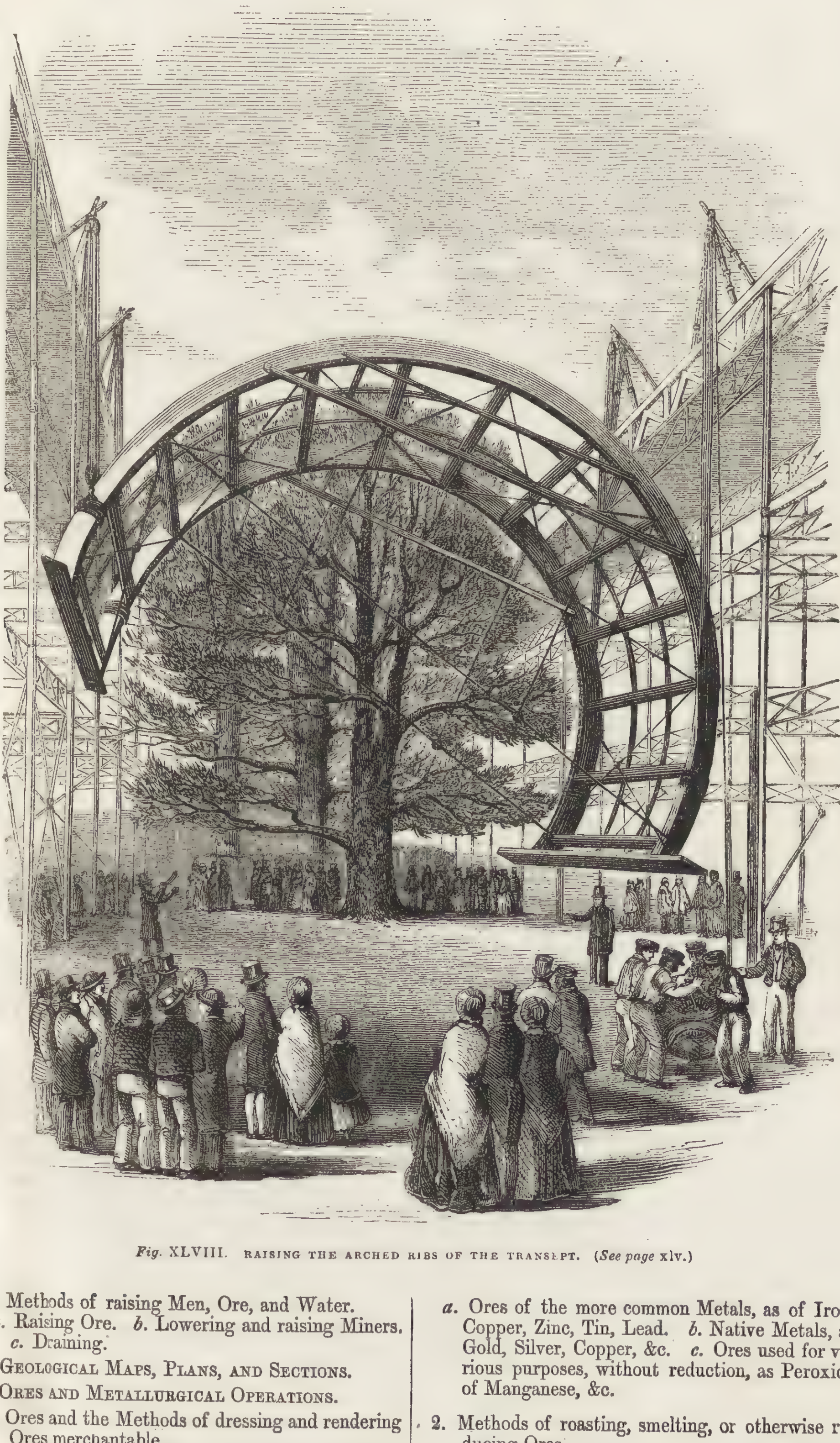


Fig. XLVIII. RAISING THE ARCHED RIBS OF THE TRANSEPT. (*See page* xlv.)

7. Methods of raising Men, Ore, and Water.
   a. Raising Ore. *b.* Lowering and raising Miners. *c.* Draining.

B. Geological Maps, Plans, and Sections.

C. Ores and Metallurgical Operations.

1. Ores and the Methods of dressing and rendering Ores merchantable.
   a. Ores of the more common Metals, as of Iron, Copper, Zinc, Tin, Lead. *b.* Native Metals, as Gold, Silver, Copper, &c. *c.* Ores used for various purposes, without reduction, as Peroxide of Manganese, &c.

2. Methods of roasting, smelting, or otherwise reducing Ores.

a. The common Metals, as Iron, Copper, Zinc, Tin, Lead. *b.* The Metals more generally used in combination, as Antimony, Arsenic, Bismuth, Cadmium, Cobalt, Nickel, &c.

3. Methods of preparing for use the nobler Metals, as Gold, Silver, Mercury, Palladium, Platinum, &c.

4. Adaptation of Metals to special purposes.
a. Metals in various Chemical states, as Iron in the condition of Cast and Malleable Iron, Steel, &c. *b.* Metals in their progress to finished Manufactures, as Pigs and Ingots, Sheets, Bars, Wires, &c.

5. Alloys, and methods of rendering more generally useful Metals and their alloys—
a. Statuary, bronze, Gun, Bell, and Speculum Metals. *b.* Brass and alloys used as a substitute for it. *c.* White alloys, as Britannia Metal, German Silver, Pewter, &c. *d.* Type, Sheathing Metals, and other alloys.

D. Non-Metallic Mineral Products.

1. Minerals used as Fuel—
a. All kinds of Coal. *b.* Lignite and Peat, and their derived products. *c.* Bituminous bodies and native Naphtha.

2. Massive Minerals used in construction.
a. For purposes of construction generally—Siliceous or Calcareous Free Stones and Flags. Granites, porphyritic and basaltic Rocks. Slates. *b.* For purposes of Ornament, Decoration, and the Fine Arts—Marbles. Alabaster, Spar, &c. Serpentine and other hard rocks susceptible of high polish. *c.* Cements and Artificial Stones—Calcareous and Hydraulic Cements. Puzzuolanas, Trap, &c. Gypsum for plaster. Artificial Stones.

3. Minerals used in the manufacture of Pottery and Glass—Sands, Limestones, &c., for Glass-making. Various Clays and felspathic Minerals, as those used for Bricks, Tiles, and various kinds of Pottery and Porcelain. Siliceous, Calcareous, and other Minerals, used in the Plastic Arts.

4. Minerals used for personal Ornaments, or for Mechanical and Scientific purposes.
a. Gems and Precious Stones. *b.* Models of Minerals and Crystals, &c. *c.* Collections of Minerals for scientific or educational use.

5. Minerals used in various Arts and Manufactures.
a. Simple bodies or compounds containing the alkalies or alkaline Earths—Those used principally for Culinary purposes or for Medicine, as Salt, Mineral Waters, &c.—Those used in various manufactures, as Sulphur, Borax, &c. *b.* Earthy and semi-crystalline Minerals.—Minerals used for grinding and polishing, as Grindstones, Honestones, Emery, &c. Lithographic Stones, drawing Chalks, and Slate Pencils. Graphite. Earthy and other Minerals used as pigments, or for staining, dyeing and colouring. Various Minerals used in Manufactures; as Alum Schist, Fuller's Earth, French Chalk, Casting Sands, &c.

6. Soils, and Mineral Manures.

Class II. *Chemical and Pharmaceutical Processes and Products generally.*

A. Chemical Substances used in Manufacture.

1. From the Mineral Kingdom.
a. Non-metallic substances. Those used principally in their elementary state, as Sulphur, Phosphorus, &c. Acids, as Sulphuric, Muriatic, Nitric, Boracic, &c. Miscellaneous Manufactures, as Sulphuret of Carbon, Chloride of Sulphur, &c. *b.* Alkalies, Earths, and their compounds.—Alkalies and their Alkaline Salts, as Soda, Potash, Ammonia, and the Carbonates, &c. Neutral Salts of the Alkalies, as Sulphate, Nitrate of Soda, Saltpetre, Borax, &c. Earths and their compounds, as Lime, Magnesia, Barytes, Strontia, Alumina, &c. *c.* The compounds of Metals proper, as Salts of Iron, Copper, Lead, &c. *d.* Mixed Chemical Manufactures, as Prussiate of Potash, &c.

2. From the Organic Kingdom, and not included in Sections III. and IV.

3. Manufactured Pigments, Dyes, and miscellaneous Chemical Manufactures. (See also Section IV.)
a. Pigments employed in House Decoration, and for colouring Woods. *b.* Pigments used for Textile Fabrics. *c.* Pigments used for Paper Hangings, and for Felted and Laid Fabrics, generally. *d.* Artists' Colours. *e.* Miscellaneous Chemical Manufactures.

B. Rarer Chemical Substances, manufactured chiefly for the Use of the Scientific Chemist.

1. From Substances of the Mineral Kingdom.
2. „ Vegetable „
3. „ Animal „

C. Chemical Substances used in Medicine and in Pharmacy.

1. From the Mineral Kingdom.
a. Non-metallic substances and their compounds. *b.* Alkalies, Earths, and their compounds. *c.* Metallic preparations.

2. From the Vegetable Kingdom, when shown for Pharmaceutical purposes. (See also Sections III. and IV.)
a. Vegetable Infusions, Decoctions, and Solutions, clear or saccharine. *b.* Tinctures. *c.* Extracts and Inspissated Juices. *d.* Resins, Gum Resins, and Oleo Resins and Balsams. *e.* Aloes, &c. *f.* Gums, as Acacia, Tragacanth, &c. *g.* Essential Oils, Cajeput, Savine, Turpentine, &c. *h.* Fixed Oils, as Castor, Croton, Almond, Olive, &c. *i.* Vegetable parts, as leaves of Digitalis, Hemlock, Henbane, roots of Jalap, Ipecacuanha, &c. *j.* Barks as imported, Cinchona, Cascarilla, Cusparia, &c. *k.* Vegeto-Alkalies, their Salts and other Crystalline principles of medicinal substances. *l.* Vegetable Acids. *m.* Miscellaneous Compounds.

3. From the Animal Kingdom.
a. Cod-liver and other Animal Oils for internal or external application. *b.* Unguents of Spermaceti, Lard, Oil, and combinations of them. *c.* Antispasmodics, as Musk, Castoreum, Civet, Ambergris, &c. *d.* Phosphorus, Ammonia, and their products. *e.* Irritants, as Cantharides. *f.* Antacids, as Crabs'-eyes, Calcareous concretions of the Craw-fish, Cuttlebone, &c.

Class III. *Substances used as Food.*

VEGETABLE KINGDOM.

A. Agricultural Produce — Cereals, Pulses, Oil, Seeds, etc.

1. Common European Cereals. 2. Cereals more rarely cultivated in Europe. 3. Millet and other small Grains used as food. 4. Pulses and Cattle Food. 5. Grasses, Fodder Plants, and Agricultural Roots. 6. The Flours or preparations of the above classes. 7. Oil-Seeds, and their Cakes. 8. Hops and other aromatic plants used for like purposes.

B. Dried Fruits and Seeds.

1. Raisins, Currants, Figs, Plums, Cherries, Apricots, &c. 2. Dates, Tamarinds, Dried Bananas, &c. 3. Almonds, Chestnuts, Walnuts, &c. 4. Cocoa-nuts, &c.

C. Substances used in the preparation of Drinks.

1. Real Teas of all kinds. 2. Substitute for Teas, as Paraguay, Arabian, Bencoolin, &c. 3. Coffee of all kinds, and Cocoa Seeds and Nibs. 4. Various substances, as Chicory Roots, Amande de Terre, Guarana Bread, &c.

D. Intoxicating Drugs, Fermented Liquors, and Distilled Spirits from unusual Sources.

1. Fermented Liquors and Spirits from unusual Sources. 2. Tobacco. 3. Opium. 4. Hemp, and other Intoxicating Drugs.

E. Spices and Condiments.

1. Cinnamon, Cassia, and their substitutes. 2. Nutmegs and Mace; Cloves and Cassia Buds. 3. Peppers, Capsicum, Mustard, Vanilla, Pimento, Cardamoms, &c. 4. Ginger, Turmeric, &c.

F. Starch Series.

1. Starches of all kinds, prepared from Wheat, Rice, Potatoes, Maize, &c. 2. Arrowroots of all kinds, Tous les Mois. 3. Sagos from the Palms, Cassava, Tapioca, &c. 4. Lichens of all kinds. 5. Other Starchy substances, as Portland Sago from *Arum Maculatum*, and from various like plants.

G. Sugar Series.

1. Sugars from the Cane and Beet. Sugars from the Maple and Palms; Birch, Poplar, Oak, and Ash; Grape Sugar. 2. Liquorice, Sarcocoll, &c.

ANIMAL KINGDOM.

H. Animal Food and Preparations of Food as Industrial Products.

1. Specimens of preserved Meats. 2. Portable Soups and concentrated Nutriment, as consolidated Milk, &c. 3. Caviare, Trepang, &c. 4. Articles of Eastern commerce, as Shark Fins, Nest of the Java Swallow, &c. 5. Honey and its preparations. 6. Blood and its preparations. 7. Industrial products, as Glue, Gelatin, Isinglass, Gluten, &c.

Class IV. *Vegetable and Animal Substances, chiefly used in Manufactures, as Implements, or for Ornaments.*

VEGETABLE.

A. Gum and Resin Series.

1. Gums of all kinds of natural occurrence. Gums made artificially, as British Gum. Mucilaginous Seeds, Barks, Pods, and Sea-weeds. 2. Resins—Resins and Balsams of all kinds. Gum Resins. Gum Elastics and Gutta Percha. Distilled Resins and Varnishes.

B. Oil Series.

1. Volatile Oils, including Camphor. 2. Drying Fat Oils. 3. Non-drying Fat Oils. 4. Solid Oils. 5. Wax. 6. Distilled Fat Oils.

C. Acids, as Acetic, Citric, Tartaric, Oxalic, &c.

D. Dyes and Colours.

1. Indigos. 2. Madders. 3. Lichens and their preparations. 4. Dyeing Barks, as Acacias, Quercitron, Mangrove, &c. 5. Woods, as Logwood, Brazil-wood, Peach-wood, Fustics, &c. 6. Flowers and Berries, as Persian Berries, Safflower, Saffron. 7. Miscellaneous, as Turmeric, &c.

E. Tanning Substances.

1. Pods, Berries, Seeds, and Fruits of various kinds, as *Algaroab*, *Acacia*, Nib-nib and Divi-divi Pods, &c. 2. Barks of various kinds, as Barks of the Babool, Brazilian Acacias, Murici, Bucida, Gordonia. 3. Galls, and similar Tanning Materials. 4. Catechu, Kino, Gambeer, &c.

F. Fibrous Substances, including Materials for Cordage and Clothing.

1. Cottons of all kinds. 2. Hemp and Flax; Manilla Hemp and New Zealand Flax. 3. China Grass, Nettle Fibre, Plantain, and Pine Apple Fibre. 4. Sunn, Jute, and other tropical substitutes for Hemp, Flax. 5. Coir, or Cocoa-Nut Fibre, Gomuti, &c 6. Rushes and Miscellaneous Substances.

G. Cellular Substances.

1. Corks of all kinds. 2. Woods and Roots used for Corks, as the *Ochroma lagopus* and *Anona palustris.* 3. Rice-paper of China. 4. Birch Bark, Pottery Bark, Citrus Rind, &c. 5. Substances used as Amadou.

H. Timber and Fancy Woods used for Construction and Ornament, and prepared by Dyeing.

1. Suited chiefly for purposes of Construction, or for the Navy. 2. Suited chiefly for Ornamental Work. 3. Prepared Woods, as by Kyan's, Payne's, Bethell's, and Boucherie's processes.

I. Miscellaneous Substances.

1. Substances used as Soap, as Quillai Bark, Soap Berries, (*Sapindus saponaria,*) Soap Roots, (*Saponaria officinalis, &c.*) 2. Perfumes, as Pucha Pat, Vetiver, Spikenard, Tonka Beans, &c. 3. Substances used mechanically, as Teazels, Dutch Rushes, &c. 4. Seeds and Fruits used for Ornamental purposes, as Ganitrus Beads, the Ivory Nut, the Doom Palm, Coquilla Nuts, Bottle Gourds, &c.

ANIMAL.

J. For Textile Fabrics and Clothing.

1. Wool, Hair, Bristles, Whalebones. 2. Silk from the Silk-worm *Bombyx Mori*, and from other species in India, *e. g. Bombycilla Cynthia* and *Attacus Paphia*. 3. Feather, Down, Fur, Skins. 4. Miscellaneous.

K. For Domestic or Ornamental Purposes, or for the Manufacture of Implements.

1. Bone, Horn, Hoofs, Ivory, Tortoise-shell, Shagreen, Quills. 2. Pearls, Seed Pearl, Mother-of-pearl, Coral and Shells generally. 3. Oils, Tallows, Spermaceti, Wax, Lard. 4. Miscellaneous, as Sponge, Goldbeater's-skin, Catgut, Silkworm-gut, Bladders, &c.

L. As Agents in the Manufacture of various Articles.

1. Glue, Isinglass, Gelatine, Bone-black, Ivory-black, Animal Charcoal.

M. For the Production of Chemical Substances.

Blood, Bones, Horns, &c., for the production of Phosphorus, the Prussiates, the Superphosphates, &c.

N. For Pigments and Dyes.

1. Cochineal and Carmine. 2. Dyes from the Galls of the Aphides. 3. Gall-stone, pigment from Ox-gall. 4. Indian Dyes from the Coccus, the various kinds of Lacs. 5. Miscellaneous, as Sepia, Enena d'Orient, &c.

MACHINERY

Class V. *Machines for direct use, including Carriages and Railway and Naval Mechanism.*

A. Steam Engines and Boilers, Water and Wind Mills, various other Prime Movers.

1. Boilers. 2. Land Engines. 3. Marine Engines. 4. Wind-mills. 5. Water-wheels and Tourbines. 6. Water-pressure Engines, as Richenback's, and Armstrong's. 7. Vacuum Power Engines. 8. Electro-Magnetic Engines, &c. 9. Miscellaneous.

B. Separate parts of Machines, Specimens of Workmanship. (See also Water and Gas-Works in Class VII.)

1. As heavy Castings or Forgings in the rough; Castings or Forgings, plain, intricate, or beautiful in the rough. 2. Specimens of Turning in Metals. 3. Specimens in filing and finished Work in Metals, such as Surfaces, Irregular Figures, &c. 4. Valves, Cocks, Pistons, Governors, &c.

C. Pneumatic Machines.

1. Air Pumps. 2. Blowing Fans. 3. Blast Engines for Furnaces, &c. 4. Miscellaneous.

D. Hydraulic Machines, Cranes, &c., Pile Drivers, &c. (See also VII.)

1. Hydraulic Machines—Pumps and Fire Engines. Water Rams. Hydraulic Presses, &c. Water-meters, &c. 2. Cranes—Any sort of Crane motion and contrivances, Jacks of all sorts. (For Windlasses, Capstans, and Blocks, see VIII. E.) 3. Piling Engines (See also VII. A.)—By hand power, or steam. Pile Sawing Machines. Pile extractors, &c.

E. Locomotives and Railway Carriages, &c.

1. Railway Locomotives. 2. Common Road Locomotives. 3. Railway Carriages, Trucks, and Waggons. 4. Railway Velocipedes, &c. &c., of all sorts. 5. Atmospheric Railway Apparatus. 6. Carriage Breaks. 7. Buffers, Couplings, &c.

F. Railway Machinery and Permanent Way.

1. Permanent Way complete. 2. Sleepers. 3. Chairs, &c. 4. Rails. 5. Switches. 6. Turn Tables. 7. Station Arrangements. 8. Signals. 9. Miscellaneous.

G. Weighing, Measuring, and Registering Machines for Commercial and not for Philosophical Purposes.

1. Commercial Weighing Instruments. 2. Instruments of Measure. 3. Registering Instruments, Gauges, Indicators, and Tell-tales.

V. *a. Carriages generally—not including those connected with Rail or Tram Roads.*

A. For Town Use.

Dress Vis-à-Vis. Dress Coach. Dress Chariot. Landau. Landaulet. Step-piece Landau. Barouche. Sociable.

B. Travelling Carriages.

Coach. Driving Coach. Chariot. Britska Chariot. Dormeuse Post Chariot. Post Chariot. Britska. Droitska. Fourgon. Invalid Carriage. Sledges, &c.

C. For General Use.

Basterna. Brougham. Double Brougham. Clarence. Pilentum. Cariole. Domestic. Driving Phaeton. Mail Phaeton. Cabriolet Phaeton. Park Phaeton. Pony Phaeton. Curricle. Cabriolet. Headed Chaise. Tilbury. Stanhope. Dennett. Gig. Irish Car. Dog Cart. Pony Chaise. Invalid Bath Chair. Velocipedes.

D. Public Carriages.

Mail Coach. Stage Coach. Omnibus. Hackney Coach. Hackney Chariot. Glass Coach. Hansom's Cab. Street Cab. Fly. Hearse. Caravan.

E. Carts and Waggons of all Kinds, not being Agricultural.

Class VI. *Manufacturing Machines and Tools or Systems of Machinery, Tools and Implements employed for the undermentioned purposes.*

A. Manufactures of all Spun, Woven, Felted, or Laid Fabrics.

1. Machinery for the complete formation from the Raw Material of all Fabrics of Cotton, Wool, Flax, Hemp, Silk, Caoutchouc, Gutta Percha, Hair. 2. Paper-making and Staining. 3. Printing and Bookbinding.

B. Manufactures of Metals.

1. The Manufacture of Metals from the Ore into Bars, Rods, Wires, Sheets, and other general forms, also casting and polishing of Metal, &c. 2. The cutting and working of Metals by Machine Tools, such as Lathes; Machines for Planing, Drilling, Boring, Slotting, Sawing, Stamping, Shearing, Riveting, Punching. 3. Machines and Tools used by the Makers of Gold, Silver, and Plated Goods. 4. Machines and Tools used by the Makers of

Cutlery, Nails, Screws, Pins, Needles, Buttons, and metallic Pens, &c. 5. Machines and Tools used by Locksmiths, Die-sinkers, &c.

C. Manufactures of Mineral Substances and Mining Machinery. (See also Section I.)

1. Machines and Tools for the preparation and working of all kinds of Glass, Stone, Granite, Alabaster, Slate, Clay, &c. 2. Machines and Tools used in the preparation and working of Gems, &c.

D. Manufactures of Vegetable Substances.

1. Machines and Tools for the preparation and working of all kinds of Wood. 2. Mills and other Machinery for Grinding, Crushing, or Preparing Vegetable Products.

E. Manufacture of Animal Substances.

Machinery and Tools for working in Horn, Bone, Ivory, Leather, &c.

F. Machinery and Apparatus for Brewing, Distilling, and Manufacturing Chemistry.

Class VII. *Civil Engineering, Architectural and Building Contrivances.*

A. Foundations and Building Contrivances connected with Hydraulic Works.

1. Application of the Screw Pile for the Foundations of Piers, Jetties, &c., Beacons, and Ships' Moorings. 2. Pneumatic Piling, Machinery illustrative of the mode of sinking and guiding the Cylinders, also Contrivances for overcoming difficulties where obstructions are offered to their sinking. 3. Coffer-dams on soft and rock bottoms, and Apparatus connected with them. 4. Foundations of Lighthouses exposed to the violent action of the sea. 5. Diving-bells, Helmets, and Apparatus connected with them. 6. Boring Tools, and Contrivances for ascertaining the stratification on Sites of intended Structures.

B. Scaffolding and Centerings.

1. Scaffolding for the erection of Brick Chimney Shafts, Columns of Masonry, Towers, and Spires. 2. Portable Scaffoldings, Ladders, and Fire Escapes. 3. Scaffolding for the erection of Monolithic Blocks, as Obelisks, &c., and for the hoisting of great Weights. 4. Fixed and Turning Scaffolding for the repairs, &c. of Domes, &c., internally and externally. 5. Scaffolding and Contrivances for the erection of large Girder Bridges, (as Britannia Bridge.) 6. Centerings for Arched Bridges, Domes, and Vaults. 7. Centerings for Tunnels, Shields, and Contrivances for facilitating their excavation.

C. Bridges, Tunnels, and Engineering Contrivances for crossing Rivers, Ravines, &c.

1. Timber Bridges. 2. Cast-iron Bridges. 3. Wrought-iron Bridges (Girder and Lattice). 4. Turning or Swing Bridges. 5. Lifting or Bascule Bridges. 6. Draw and Rolling Bridges. 7. Suspension Bridges. 8. Temporary Bridges (see also VIII. M). 9. Floating Bridges, as across the Hamoaze, and to receive Railway trains, as across the Humber. 10. Examples of Brick and Stone Bridges.

D. Dock, Harbour, River, and Canal Works.

1. Docks and Slips for the building and repair of Ships. 2. Mercantile Docks, and Arrangements connected therewith, for the loading and unloading of Ships. 3. Sea and Canal Locks, Gates and Entrances, Stop-gates, Sluices, &c. 4. Marine Railway Slips and Hydraulic Docks. 5. Harbours of Refuge. 6. Breakwaters, Piers, Jetties, Wharfs, and Landing-piers. 7. Groynes, Sea-defences, &c. 8. Perpendicular Lifts for Canals, and other Engineering contrivances instead of Locks. 9. Dredging-machines, Hedgehogs, and other Machines employed in Harbour Works, for removing Shoals, &c.

E. Lighthouses and Beacons.

F. Roofs, Buildings, and Contrivances for covering large Areas.

1. Examples of Timber and Iron Trusses. 2. Roofs for Markets, Railway Stations, &c. 3. Roofs for Theatres. 4. Fire-proof Buildings, arranged so as to be applicable to the economical methods of construction. 5. Coverings for Roofs.

G. Water Works, and the Engineering Contrivances connected with the Obtaining, Storing, and Distribution of Water in Towns.

1. Well-sinking and Boring; and the Apparatus connected therewith. 2. Storing, Filtering, and Distributing Reservoirs, and the contrivances connected with them. 3. Contrivances for maintaining and producing efficient Heads, and the Apparatus connected with Street Mains. 4. Services; and Apparatus connected with Domestic Water Supply. (See also V. B.)

H. Gas Works, and Contrivances connected with the economical Production of Artificial Light.

1. Retorts and Distillatory Apparatus. 2. Condensing, Separating, and Purifying Apparatus. 3. Governors and Station Meters. 4. Gauges, Valves, and Contrivances connected with the Mains for the distribution of Gas. (See also XXII.)

I. Sewerage, Cleansing, Paving, and the Contrivances connected with the Sanitary Condition of Towns.

1. Forms of Sewers, their Entrances and Junctions. 2. Contrivances for Cleansing, Flushing, and Ventilating Sewers. 3. Contrivances for removing and distributing Sewage. 4. Traps, and other means of preventing emanations. (See also XXII.) 5. House Drains, and the internal Sanitary Arrangements of Houses. (See also XXII.) 6. Pavements.

J. Warming and Ventilating Domestic Residences, and the Contrivances connected therewith.

1. Arrangements for Warming, as with Hot Air, Water, Steam, &c. 2. Contrivances for preventing Smoke, and Chimney-sweeping Machines. 3. Contrivances for Ventilation on a large Scale.

K. Miscellaneous.

Class VIII. *Naval Architecture, Military Engineering; Ordnance, Armour, and Accoutrements.*

A. Illustrations by Models of Ship-building for purposes of Commerce.

1. Ships. 2. Barks. 3. Brigs and Brigantines. 4. Snows and Ketches. 5. Schooners. 6. Sloops and Cutters. 7. Luggers, Barges, &c.

B. Illustrations by models of Ship-building for purposes of War

1. Ships of the Line. 2. Frigates. 3. Sloops, Corvettes, and Brigs. 4. Cutters, Brigantines, Ketches, Schooners, Barges, &c. 5. Bomb or Mortar-vessels, Fire-ships, Gun-boats, &c.

C. Illustrations by Models of Ship-building for the application of Steam or other Powers.

1. Great War Steamers. 2. Steam-vessels of large burden for long Passages. 3. Steam-vessels for Inland, River or Lake Navigation. 4. Sailing-vessels fitted for the temporary appliance of Steam or Human Power. 5. Miscellaneous.

D. Vessels used for Amusement, and Small Vessels generally.

1. Seagoing Yachts of all kinds. 2. River Yachts, and Pleasure Boats of a smaller class. 3. Rowing Boats of all kinds. 4. Fishing Boats and Vessels. 5. Life Boats and Paddle-Box Boats.

E. Rigging, Anchors, Windlasses, Capstans, Sheathing, and Articles connected with practical Seamanship and the saving of Life from Shipwreck.

F. Infantry Army-Clothing and Accoutrements.

G. Cavalry Army-Clothing and Accoutrements.

H. Camp Equipage, such as Marquees, Tents, &c.

I. Naval Gunnery and Weapons of Attack and Defence, more especially adapted to Naval Purposes.

J. Artillery Equipments, both in Garrison and the Field, Machines for Mounting and Dismounting Ordnance.

1. Garrison Equipments. 2. Field Equipments. 3. Machinery for Mounting and Dismounting, and transporting Ordnance, Carriages, &c.

K. Ordnance, and Projectiles.

1. Guns. 2. Howitzers. 3. Mortars. 4. Shot, shells, and other Projectiles.

L. Small Arms.

1. Rifles. 2. Muskets. 3. Carbines. 4. Pistols. 5. Lances. 6. Swords. 7. Bayonets. 8. Cartridges.

M. Military Engineering, Field Equipments, Methods of Passing Rivers and other Obstacles, the Attack and Defence of Fortresses, and Field Fortification.

1. Field Engineer Equipments. 2. Military Bridges, Pontoons, Rafts, Boats, &c. 3. Field Fortification, and Materials used in the attack and defence of Fortresses. 4. Permanent Fortification.

Class IX. *Agricultural and Horticultural Machines and Implements.*

A. Implements for Tillage.

1. Ploughs, including Subsoil Ploughs, and Pulverisers. 2. Harrows. 3. Scarifiers, Cultivators, and Grubbers. 4. Clod Crushers and Norwegian Harrows. 5. Rollers. 6. Digging and Trenching Machines.

B. Driling, Sowing, Manuring, and Hoeing Machines.

1. Pressers. 2. Drills. 3. Dibblers. 4. Horse Hoes. 5. Broadcast Sowing Machines. 6. Contrivances connected with the distribution of Manure.

C. Harvesting Machines.

1. Machines for cutting Corn or Grass. 2. Tedding Machines for Hay. 3. Rakes for Hay, Corn, Stubble, &c.

D. Barn Machinery.

1. Steam Engines, and Water Power Machines. 2. Horse Works. 3. Thrashing Machines. 4. Straw Shakers. 5. Winnowing, Corn Cleaning, and Barley Hummelling. 6. Crushing, and Splitting Mills. 7. Flour and Meal Mills. 8. Chaff Cutters. 9. Corn Weighers and Meters. 10. Gorse Bruisers and Cutters. 11. Chicory Cutters. 12. Cider Presses.

E. Field, Fold, and Yard Machinery.

1. Turnip-cutters. 2. Root Grating and Squeezing Machines. 3. Potato-washers. 4. Steaming Apparatus. 5. Feeding Apparatus. 6. Weighing Machines for Cattle, &c. (See G.V.) 7. Watering Engines, for Fire, or Garden Purposes. (See D. V.) 8. Contrivances connected with the Stack-yard and Storing. 9. Contrivances for Fencing, Folding, &c. 10. Fittings for Stables, Cow-Houses, &c.

F. Agricultural Carriages, Harness, and Gear.

1. Waggons, Carts, &c. 2. Brakes. 3. Separate parts, as Wheels, Axles, &c. 4. Harness and Gear.

G. Drainage Implements.

1. Machines for making Pipes, Tiles, and Bricks. 2. Implements for Draining, and Tools. 3. Tiles, Pipes, and other Materials used in Draining. 4. Scoop Wheels and other Machines used in Draining or Lifting Water. 5. Machines and Contrivances for Irrigating Lands. 6. Sluices, Draw Gates, &c.

H. Dairy Implements.

1. Churns. 2. Cheese-presses. 3. Miscellaneous Contrivances used in the Dairy.

I. Miscellaneous Implements used in Agriculture—

1. Rick Ventilator. 2. Ladders. 3. Pitch and Tar Melters. 4. Sheep-dipping Apparatus. 5. Farm Railway. 6. Models of Farm Buildings. 7. Alarm Gun for Protecting Crops. 8. Beehives. 9. Instruments for Cattle, Probangs, &c. 10. Tree Remover. 11. Various Miscellaneous Articles.

J. Garden Engines and Tools.

Class X. *Philosophical Instruments, and Processes depending upon their use: Musical, Horological, and Surgical Instruments.*

A. Instruments for the Measurement of Space.

1. In fixed observatories, as Transits, Transit Circles, Great Quadrants, Mural Circles, Zenith Sectors, Altarimeters, Equatorials, Collimators, &c.

2. For Nautical Astronomy and Observations, as Sextants, Reflecting and Repeating Circles, Dip Sectors, &c.

3. Astronomical and Topographical Illustrations, as Globes, Orreries, Planetariums, Maps, Charts, &c.

4. Optical Instruments, as great Refracting and Reflecting Telescopes, with their appurtenances, equatorial motions, &c.

5. Apparatus subordinate to Graduated Instruments, as divided Object Glasses and Heliometers, Eye-pieces, Micrometers, Micrometer Microscopes, &c.

6. Survey Instruments.
a. Topographical, as Base Apparatus, Theodolites, Repeating Circles, Geodetic Signals, Levelling Apparatus, Miners' and Prismatic Compasses, Pocket Sextants, Perambulators, Pedometers. *b.* Hydrographical, as Sounding Machines, Patent Logs, Current Meters, Silometers.

B. Instruments to Measure the Effects of Mechanical and Physical Forces.

1. Mechanical, as Dynamometers, Tachymeters.
2. Mass (Weighing Instruments), as Weighing Machines, Scales, Chemical and Assay Balances.
3. Density, as Areometers and other Instruments to determine Specific Gravity, Invariable Pendulums, Atwood's Machine.
4. To measure other Physical Effects, including Meteorological Instruments, as Barometers, Hydrometers, Eudiometers, Thermometers, Pyrometers, Electrometers, Rheometers, Magnetometers, &c.

C. Instruments to illustrate the Laws of Mechanical and Physical Science.

1. "Kinematics,"—Instruments to exhibit and describe Motions and their Combinations, as Compasses, Pentagraphs, Instruments for describing Elliptical and other Figures, &c.
2. Mechanics, or Instruments to illustrate the Laws of Static and Dynamic Forces.
a. Stereo-Mechanics, as for illustrating Mechanical Powers, accelerated and retarded motion, Equilibrium and Parallelogram of Forces, Levers, Cathetometers, Centripetal and Centrifugal Forces, Elasticity, &c. *b.* Hydro-Mechanics, as Instruments to illustrate the Motion and Impinging Force of Waves, &c. *c.* Pneumo-Mechanics, as Apparatus connected with the Air Pump, &c.
3. Instruments to illustrate the laws of Corpuscular Forces, as Whitworth's Planes, Endosmometers, &c.
4. Instruments to illustrate the Laws of Sound.
5. " " " Light.
6. " " , Heat.
7. " " " Electricity, including Voltaic and Thermo-Electricity, Magnetism, Electro-Magnetism, Magnetic Electricity, Dia-Magnetism, &c.

D. Application of Mechanical and Physical Science to Useful Purposes, not included in any of the Preceding or Subsequent Sections.

1. Mechanics.
a. Stereo-Mechanics / *b.* Hydro-Mechanics { when not included in Sections describing their more extended uses.
c. Pneumo-Mechanics, as Air Pumps, Rarefying and Condensing, Diving Bells, Air Balloons, &c.
2. Sound (not including Musical Instruments).
a. Instruments to assist Hearing. *b.* Alarums, Bells. *c.* Models of Acoustical Buildings, &c.
3. Light—Instruments to assist Vision, as smaller Telescopes, Opera Glasses, Spectacles, Microscopes; Lenses, Mirrors, Signals, Visual Telegraphs, Lighthouses, Optical Illusions, Gas and Solar Microscopes, Cameras, Photography, Polarization of Light, &c.
4. Heat—Apparatus for producing Heat, for Freezing, Thermostats, Burning Lenses, and Mirrors, &c.
5. Magnetism and Electricity—Mariners' Compasses, Electric and Electro-Magnetic Telegraphs, Electric Light, Applications of Electro-Magnetism as a Motive Power, Therapeutic Applications of Electricity, Electrotype Apparatus and Specimens, &c.

E. Chemical and Pharmaceutical Apparatus.

F. Miscellaneous.

X. *a.* *Musical Instruments, &c.*

A. Wind Instruments.
1. Wood—Flutes (also in Metal, &c.). Flageolets. Oboes. Clarinets. Bassoons. Serpents. 2. Metal—French Horns. Trumpets. Bugle Horns. Cornets à Pistons. Cornopeans. Trombones. Ophicleides.

B. Stringed Instruments.
Harps. Guitars. Violins. Violas. Violoncellos. Double Basses.

C. Keyed Instruments with fixed Tones.
Organs. Piano-fortes. Seraphines. Harmoniums. Concertinas. Accordions.

D. Instruments of Percussion.
1. Drums.—Bass Drums. Kettle Drums. Side Drums. Tambourines. 2. Cymbals. Triangles.

E. Automatic Instruments.
Mechanical Organs. Musical Boxes, &c.

F. Miscellaneous Articles in connexion with Musical Instruments.
Tuning Forks, Tuning Hammers, Pitch Pipes, &c. Wire Strings, Catgut Strings, &c.

G. Musical Diagrams.

X. *b.* *Horology.*

A. Great Clocks for Churches, Castles, Stables, and Public Buildings in General.
1. With 3 and 4-wheel Trains. 2. With Remontoires and with various Escapements. 3. To strike the Hours, and the Hours and Quarters. 4. The various Compensation Pendulums in use. 5. The various Modes of making the Work to carry the Hands, and communicating the Motion from the Clock to the Hands. 6. Electric or Magneto-electric Clocks.

B. Astronomical Clocks.
1. The various Escapements employed. 2. The various Compensation Pendulums used. 3. Equation Clocks. 4. Clocks, commonly called Journeymen Clocks, for Observatories.

C. Clocks applied in Registration.
1. To register the Barometer daily for twelve months, or other periods. 2. To register Tides and Winds. 3. To register the punctual attendance of Watchmen and others.

D. Clocks showing different Phenomena.
1. Cycle of the Sun and Moon, Eclipses, Moon's Age, Equation of Time, the Golden Number, Tides, &c.

E. Clocks for the Common Purposes of Life—

1. Weight Clocks. 2. Spring Clocks with Pendulums. 3. Balance Clocks of various descriptions.

F. Clocks and Time-pieces in Decorated Cases, commonly called Ornamental Clocks, for Drawing-rooms, Libraries, &c.

1. In Metal Cases, Gilt and Lacquered. 2. In Buhl Cases. 3. In Wood Cases. 4. In China Cases.

G. Sundries applicable to Clocks.

1. The various Modes by which Clocks are kept going while being wound. 2. The various Escapements employed in Clocks of different descriptions. 3. Various portions of Mechanism forming parts of, or applicable to, Clocks.

H. Marine Chronometers.

1. Eight-day. 2. Two-day. 3. Thirty-hour. 4. The various descriptions of Compensation Balances applied to Chronometers. 5. The various descriptions of Pendulum Springs applied to Chronometers. 6. Pocket Chronometers.

I. Pocket Watches of various descriptions.

1. For measuring Minute Portions of Time and registering Observations. 2. With Compensation Balances. 3. With Duplex Escapement. 4. With Horizontal Escapement. 5. With Lever Escapement upon different constructions. 6. With the old original Vertical Escapement. 7. Repeaters upon different constructions to strike the Hours and Quarters. 8. The same to strike the Hours, Quarters, and Half-quarters. 9. The same to strike the Hours, Quarters, and Minutes. 10. Clock-watches to strike the Hours and Quarters in a similar manner to Clocks. 11. Clock-watches and, in addition, Repeaters. 12. Watches with alarums. 13. Watches known by the denomination of Ladies' Watches, with the cases decorated in various ways. 14. Various portions of Mechanism forming parts of Watches.

J. Watches for different Markets—

1. As for Turkey, with three Cases, and Turkish Dials. 2. For China, with peculiar Cases and Dials. 3. For India and South America. 4. For Home Country districts.

K. Miscellaneous.

Class X. *c.* *Surgical Instruments.*

[As the particulars of this subdivision are interesting and intelligible omy to members of the medical profession, they are omitted here.]

MANUFACTURES.

Class XI. *Cotton.*

A. Cotton Yarn and Thread.

1. Grey Twist in Hanks and Bobbins, from No. 20 to 600—White and Bleached Yarn. Dyed Yarn, assorted Colours. Dyed Yarn, Turkey-red and Pink. 2. Cotton Thread—Two-fold lace; 2, 3, 4, 6, and 9-cord sewings. Two-fold Lisle; knittings. Crochet Cotton. Wire Thread. 3. Crape Yarn —Bleached. Coloured.

B. Calicoes.

Sheetings (Grey and Bleached)—$\frac{7}{8}$ and $\frac{9}{8}$, Super. Shirtings (Grey and Bleached). Domestics. Madapollams—$\frac{7}{8}$ and $\frac{9}{8}$, and 40-inch Printers'. Long-cloths (Plain and Twilled)—Imitation Irish.

C. Cords and Beaverteens.

1. $\frac{1}{2}$ ell and $\frac{3}{4}$ Cords—Genoa. Beaverteens. 2. Drabbetts. Twilletts. Fancy Drills. Grey Twills. Swansdowns. Jeans. Ticks. 3. Velvets and Velveteens.

D. Muslins, &c.

1. Cambric and Jacconet — Mulls and Books. Bishop and Victoria Lawns, &c. Jacconets, Organdies, Lenos, and Fancy Checks for Printing (Grey and Bleached). 2. Figured Muslins—Lappets, Lenos, and Netts, White and Dyed. Jacquard-made Goods. Lappets, Japan Spots and Honeycombs. Lappets, Striped and Corded. Lappets, Allover and Diagonal Spider. Lappets, Bengal Scarf Spot assorted. Harness, assorted. Harness Garments. Window Curtains. Spot. Book Jacconet and Dacca Lappets. Lenos, Plain and Figured. Small Stripe and Check Doriahs. Mexican Lappets, Coloured and White. Turkey Gauze, White and Dyed. 3. Shawls, Handkerchiefs, and Dresses—Imitation Cambric Handkerchiefs, Plain and Embroidered. Lappet Shawls. Book Muslin Dresses, Checks. Tapes and Cords. Book Handkerchiefs. Specimens of Madapollams. Bleached Goods of various Finishes. Bleached Goods of Cambric Finish. Bleached Goods of Jacconet Finish. Book Muslins, Hard, Elastic, and London Finish. Book Muslins, richly Ornamented.

E. Dimities, &c.

1. Furniture Dimities, Plain and Figured—Hair, Cord, and India, Plain and Figured. Quilting. Satteen and Twilled Jean. 2. Marseilles and Summer Quilts—Counterpanes (White and Coloured). Toilet Covers (Plain and Coloured). Anti-Macassars. Grey Sheets. Window Hollands. Cotton Diapers and Damasks.

F. Coloured Woven Cotton.

1. Handkerchiefs for the Pocket, Head, Neck, and Shoulders—Imitation Madras and Pulicat. Imitation Java and Manilla. Fancy White Grounds, Checks. Imitation Manilla Pine Apple Cloth. Imitation White Cambric. Imitation White Cambric Figured Borders. Cravats, assorted colours. 2. Ginghams. Common Light grounds, assorted, Plain. Common Dark Grounds, assorted, Plain. Earlston Ginghams. Power-loom Seersuckers and Checks. Turkey-red Grounds. Blue and Black heavy Checks. Muslin Ground, Stripes and Checks. Furniture, Stripes and Checks. Coloured Diapers. Crossover Stripes. Jean Stripes. Derries. Hungarians. Umbrella Ginghams. 3. Dresses, Scarfs, &c.—Java Bugis, and Manilla Sarongs. Java Chindies and Scarfs. 4. Zebras—Blue and White Striped Dresses. Orange-pine Striped Dresses. Blue-pine Striped Dresses. Robe de Chambre.

G. Oiled Calicoes or Cambrics for Packing.

Localities of Exhibition.

A. 1, 2, 3. Manchester, Carlisle, Glasgow, Paisley, Meltham, near Huddersfield. B. Manchester, Preston, and Lancashire, generally; Glasgow. C. Lancashire. D. 1. Manchester, Preston, Chorley, Bolton, Glasgow; 2. Glasgow, Paisley, Dunfermline; Manchester. 3. Glasgow, Paisley.

Localities of Exhibition.

D. 3. Manchester, Glasgow. E. Manchester, Bolton, Glasgow. F. 1. Manchester, Carlisle, Glasgow; 3. Glasgow, Paisley, Carlisle, Belfast. G. Manchester, Glasgow.

Class XII. *Woollen and Worsted.*

A. Broad Cloths.

1. Single Milled, 52 to 63 inches wide. Wool-dyed Woaded Colours—Blue, Black, Medleys, Oxford and other mixtures. (The term "Medleys" includes all Wool-dyed Colours, excepting Blue and Black.) Wool-dyed, common colour Unwoaded.—Black, Medleys; Oxford and other Mixtures; Drab. Piece-dyed, Woaded Colours —Black, Blue, and Fancy Colours. Piece-dyed, Unwoaded—Black, Scarlet, Gentian, and other Fancy Colours. 2. Double-milled, 52 to 75 inches wide. Subdivided same as No. 1. 3. Medium-cloths, 54 to 63 inches wide. Subdivided same as No. 1. 4. Ladies'-cloths, 54 to 63 inches wide. Subdivided same as No. 1. 5. Venetians, 54 to 58 inches wide. Subdivided same as No. 1. 6. Army-cloth, 52 to 54 inches wide. Subdivided same as No. 1. 7. Beavers. Subdivided same as No. 1. 8. Pilots. Subdivided same as No. 1. 9. Mohair, 54 to 58 inches wide. Subdivided same as No. 1. 10. Cloakings, 54 to 58 inches wide. Subdivided same as No. 1. 11. Tweeds—Single-milled; Double-milled and Treble-milled. 12. China Stripe Cloths list piece dyed, and other Cloths, 60 inches wide. 13. India Cloths, piece-dyed, 60 inches wide. 14. Billiard Cloths, piece-dyed, 72 to 81 inches wide. 15. Elastic Glove Cloth, 54 to 70 inches wide. Subdivided same as No. 1. 16. Union Cloths, Cotton Warps, piece-dyed, 52 to 54 inches wide. 17. Double Colours, piece-dyed, 54 to 63 inches wide.

B. Narrow Cloths.

1. Cassimere, Double-milled, 27 to 29 inches wide. Subdivided same as Broad Cloths, No. 1. 2. Cassimere, Single-milled, 27 to 29 inches wide. Subdivided same as No. 1. 3. Doe-Skins, Treble-milled, 27 to 29 inches wide. Subdivided same as No. 1. 4. Doe-Skins, Double-milled, 27 to 29 inches wide. Subdivided same as No. 1. 5. Doe-Skins, Single-milled, 27 to 29 inches wide. Subdivided same as No. 1. 6. Cashmerettes, 27 to 29 inches wide. Of all Colours. 7. Tweeds, Wool-dyed, 27 to 29 inches wide. Double and Single-milled. 8. Fancy Trowserings.

Localities of Exhibition.

A. 1. Chippenham, Wilts; Frome, Somersetsh.; Bradford, Wilts; Wootton-under-Edge, Stroud, Leeds, Huddersfield. Melksham, Trowbridge, Bath, Tiverton, Frome, Darsley, Saddleworth. 2. Leeds and Stroud; 3, 4. Huddersfield, Leeds, Stroud, and Wootton-under-Edge; 5. Trowbridge, Huddersfield, Leeds; 6. Halifax, Stroud, Huddersfield, Leeds, Dewsbury. 7. Leeds and Frome. 8. Leeds, Halifax, Huddersfield, Dewsbury. 9, 10. Leeds, Huddersfield. 11. Trowbridge, Huddersfield, Galashiels, Hawick, Selkirk. 12. Leeds. 14, 15. Stroud, Leeds, Huddersfield. B. 1. Leeds, Huddersfield, Stroud, Trowbridge. 2. Stroud, Leeds. 3—6. Huddersfield, Trowbridge, Wootton-under-Edge, Frome. 7, 8. Trowbridge, Huddersfield, Selkirk, Galashiels, Hawick.

C. Flannel.

1. Saxony Flannel. White and Coloured. 2. Various Flannels. Lancashire, Real Welsh, Imitation Welsh and Bath Coating.

D. Blankets.

1. Cloth Blankets. 2. Superfine Blankets. 3. Medium Blankets. 4. Ordinary Blankets.

E. Woollen Cloaking.

1. Plain. 2. Mixtures. 3. Fancy.

F. Serges.

Long Ells, White and Coloured.

G. Tartans.

1. Plain. 2. Fancy.

H. Worsted Stuff Goods.

1. Fabrics composed entirely of Wool. Merinos. Shalloons, Says, Serges, and Plainbacks. Calimancos, Plain and Figured. Lastings, Princettas, Serges de Berry. Coatings. De Laines. Alepinas. Durants and Buntings. Moreens. Damasks. Damask Aprons, Damask Table Covers, &c. Russels. Camlets. 2. Fabrics composed of Wool and Cotton. Cobourg and Paramatta Cloths. Union Double Twills. Plain Orleans Cloths, Single and Double Warps. Plain Muslin de Laines, Barèges, &c. Shawl Cloths. Union Coatings. Union Lastings, Princettas, and Serges de Berry. Stockinetts. Fancy Lastings. Fancy Worsted and Cotton Goods. Figured Cobourgs, Orleans, &c. Aprons, plain and figured. Linings, plain and figured. Union Damasks. Union Damask Table Covers, &c. 3. Fabrics composed of Wool and Silk. Silk-warp Cobourgs and Orleans. Silk-warp Double Twills. Silk-warp Coatings. Silk-warp Russels. Silk-weft Lastings. Silk-warp Damasks. 4. Fancy Goods composed of Wool, Silk, and Cotton. 5. Fabrics composed of Alpaca and Mohair, mixed with Cotton or Silk. Plain Alpaca Lustres. Plain Alpaca Mixtures. Twilled Alpaca Mixtures. Plain Mohair Lustres. Silk-warp Alpaca Lustres. Alpaca and Mohair Linings. Alpaca, Mohair, and Silk Fancy Goods. Alpaca Umbrella and Parasol Cloth.

I. Woollen, Worsted, Alpaca, and Mohair Yarns.

Localities of Exhibition.

C. Stroud, Rochdale, Wales, &c. D. Dewsbury, Yorkshire, Okehampton, Devonshire: Clickheaton, Heckmondwike, Witney, &c. E. Leeds, Huddersfield. F. Halifax, Rochdale. G. Paisley, Galashiels, &c., Huddersfield. H. Bradford, Halifax, Leeds, Keighley, Bingley, &c. I. Bradford, Huddersfield, Leeds, &c.

Class XIII. *Silk and Velvet.*

A. Silk Yarns.

1. Spun Silks. 2. Thrown Silks. 3. Sewing Silks.

B. Plain Silks.

1. Gros, Sarsnets, Persians, Satinets, Armures, and other plain Silks. 2. Satins, black or coloured. 3. Armozines, Barattees, and Serges. 4. Serges and Lutestrings, for Parasols and Umbrellas. 5. Brussels, Ducape, Satin, and other plain Cravats and Scarfs for Men's wear. 6. Satin twilled and other plain Handkerchiefs for Ladies' wear. 7. Bandannas, Corahs, and other Cloth for printing. 8. Spun Silk Handkerchiefs (for printing).

Localities of Exhibition.

A. London, Manchester, Derby, Macclesfield, Huddersfield. B. London, Manchester, Macclesfield, Congleton, Coggleshall, Braintree.

C. Fancy Silks.

1. Shot, striped, checked, watered (moiré), shaded, clouded (chiné), or striped with Satin. 2. Floret, Damask, Tobine, Brocade, and other Figured Silks. 3. Figured Vestings, Cravats, and Scarfs.

Localities of Exhibition.

C. London, Manchester, Macclesfield, Leek.

4. Figured Handkerchiefs, Scarfs, Aprons, and Veils, for Ladies' wear. 5. Parasol and Umbrella Silks figured, or with figured borders. 6. Furniture Damasks and Brocades. 7. Gold and Silver Tissues, figured and plain. 8. Figured Pocket Handkerchiefs, for Gentlemen's wear.

D. Velvets.

1. Plain Velvets, black and coloured. 2. Plain Terry. 3. Figured and Embossed Velvets. 4. Plush (Ladies', &c.). 5. Hat Plush.

E. Gauzes and Crapes.

1. Lisse, Areophane, and other Gauzes. 2. Plain and coloured Crapes. 3. Figured Gauze (Blonde, &c.). 4. Fancy Gauze or Crape Handkerchiefs.

F. Plain Ribbons.

1. Sarsnet and Lutestring Ribbon. 2. Satin Ribbons. 3. Gauze Ribbons. 4. Velvet Bands or Bindings.

G. Fancy Ribbons.

1. Shot, striped, checked, shaded, clouded (chiné), or striped with satin. 2. Figured or Brocaded. 3. Gauze or Crape, with brocaded or cut figures. 4. Embossed Satin. 5. Figured or checked Velvet.

Localities of Exhibition.

D. London, Manchester, Macclesfield, Aylesbury, Sudbury, Braintree, Coggleshall. E. Paisley, Macclesfield, Manchester, Norwich, Yarmouth, Bungay, Braintree, Bocking, Halstead, Ditchenham, Ponder's End, &c. F. Congleton, Macclesfield, Coventry, Nuneaton. G. Coventry, Nuneaton, Derby, Congleton.

Class. XIV. *Manufactures from Flax and Hemp.*

A. Flax Fibre.

1. Steeped scutched Flax Fibre, both systems. 2. Unsteeped Flax Fibre from dried Straw. 3. Hackled Flax from both systems, and Hackled Tow. 4. Tow from both systems, and from the unsteeped process. 5. Tow in the forms to mix with wool. 6. Flax, Hemp, &c., prepared as a substitute for Cotton and Silk.

B. Linen Yarn and Thread.

1. Linen Yarn, Thread, &c.: English, Scotch, and Irish, (Tow and Linen Yarn, 1½ to 400 lea.) 2. Hand-spun Thread as used for some fine Cambrics, &c., (240 to 800 lea.) 3. Dyed Yarns and Threads of various colours. 4. Dyed Yarns and Threads to resemble Lustre of Silk. 5. Flax-Cotton, Flax-Fibre, Flax-Wool, and Flax-Silk Yarns. 6. Flax Thread from unsteeped Fibre.

C. Plain Linens of all widths, Bleached, Unbleached, and Dyed.

1. Canvas—English, Scotch, Irish, French, Dutch, and Russian. 2. Heavy Linens—As Crash, Huckabacks, Glass cloths, and Sheetings: Yorkshire, Newark, Scotch, Drogheda, Courtrai, Ghent, Russia. Tubing for Irrigation, and Banding for Machinery. 3. Irish Manufacture—Brown, Black, and coloured Linens. 4. Platillas, Creas, Britannias, German ditto. 5. Irish Linens and Sheetings—Courtrai, Ghent, Bielefield, Prussian.

D. Damasks, Diapers, Drills, and other Twilled Linens: Bleached, Unbleached, or Dyed.

1. Damasks and Diapers—English, Scotch, Irish, Saxon. 2. Drills—English, Scotch, Irish, French, Saxon, Russian. 3. Linen Velveteens, Linen Velvets, and Linen Cords.

E. Cambrics, Cambric and Linen Handkerchiefs, Plain, Bordered, Embroidered, Plain Printed or Dyed, Printed Linens, Lawns, Cambrics, Bleached, Unbleached, or Dyed.

1. Irish. 2. French. 3. Irish, Scotch, and Swiss Embroidering (in Cambric).

F. Cordage of all kinds.

Ropes, Lines, Twines, Nets, &c.

Localities of Exhibition.

A. Leeds, Hull, Newcastle-on-Tyne, Manchester, Huddersfield, Bradford, Rochdale, Belfast, &c. B. Leeds, Gilford near Belfast, Dundee, Belfast, Manchester, Huddersfield, Bradford. C. Belfast, Armagh, Balymena, Bridport, Dundee, Barnsley, Forfar, Drogheda, London, Kirkaldy, Arbroath. D. Belfast, Dunfermline. Barnsley, Manchester. E. Belfast, Armagh, Warringstown. F. Belfast, Bridport, Dundee, London, Liverpool, &c.

Class XV. *Mixed Fabrics, including Shawls; but exclusive of Worsted Goods* (*Class XII.*)

A. Mixed Woven Fabrics.

1. Cotton Warp, plain, watered, or figured. Shot with Wool or Worsted; with Mohair, Linen, Silk, Silk and Worsted, Silk and Cotton, and with China grass. (For Dresses, Damasks, Aprons, Shoe and Boot-cloths, Linings, Cravats, Vestings, Ponchos, Pantaloons, Shawls, Scarfs, Coatings, Tweeds, Quiltings, Plaids, &c.) 2. Spun Silk Warp, plain, watered, or figured. Shot with Wool or Worsted; with Mohair, Linen, Net Silk, Silk and Worsted, and with all Cotton. (For Dresses, Damasks, Vestings, &c.) 3. Silk Warps, plain, watered, figured, or embossed. Shot with Cotton; with Wool or Worsted, Mohair, Linen, Cotton and Silk, and with Cotton and Worsted graduated. (For Tabinets; Poplins; Paramattas; Chalis; Bareges; Cashmeres, &c.) 4. Linen Warps, plain, watered, or figured. Shot with Wool or Worsted; with Mohair, Cotton and Silk, and with Silk. 5. Cotton and Silk Warps, plain, watered, or figured. Shot with Cotton; with Mohair, Silk, Worsted, and China Grass. (For Dresses, Articles of Furniture, Shawls, &c.)

B. Shawls.

1. Woven Shawls.—Chenille all Silk or Silk and Cotton. Cashmere from the East. Imitation Cashmeres, that is, Harness, or Jacquard Wove Shawls. Plain Silk and Satin. Figured Silk and Satin. Crape, plain and embroidered. Gauze, plain and figured. Lace, plain and figured. Shetland or knitted Woollen. Barege, all Wool and Silk and Wool. Grenadine and other thin texture, in Silk and Silk and Wool. Embroidered Lace, Silk, and Cashmere. Woollen, plain, tartan, and fancy. 2. Printed Shawls.—Barege. Silk, including silk, grenadine, and other thin mixtures. Cashmere. Chiné, or Shawls printed on the warp before they are woven.

Localities of Exhibition.

A. Huddersfield, Bradford, and their neighbourhoods, Manchester, Norwich, Dublin, Halifax, Glasgow, Paisley, Dolgelly, Caernarvon, Conway, Anglesea.

B. London, Paisley, Norwich, Halifax, Huddersfield, Leeds, Edinburgh, Glasgow, Galashiels, Kinross, Hawick, Selkirk.

Class XVI. *Leather, including Saddlery and Harness, Skins, Fur, Feathers and Hair.*

A. Leather.

1. Rough tanned Leather. Tanned Butts—Crop-hides, Offal, (*i e.* Shoulders and Bellies,) Horse Butts, Dressing-hides, Horse-hides, Kips, Calf-skins, Seal-skins, Hog-skins, Bazils, Varieties. 2. Curried Leather. Curried Calf-skin, Russett (*i. e.* Natural Colour), Waxed (*i. e.* Black), Butts, Russett and Waxed. Curried Kips, Russett and Waxed, Cordovan, Waxed, Cordovan, Grain, Shoe-hides, Seal-skins, Dog-skins, Goat-skins, Boot-legs, Boot-fronts, Varieties, Saddlers' Hides, Rein Hides, Collar Hides, Chaise Hides, Pouch and Scabbard hides, Powder Hides, Bellows Hides, Pipe Backs, Bag Hides, Pig Skins, Hog Skins, Russia Leather. 3. Enamelled Leather. Black Enamelled Horse-hides, Cow-hides, Calf-skins, Seal-skins, Goat-skins, Roans and Skivers. Coloured Enamelled Calf-skins and Sheep-skins. Black Japanned Horse-hides, Cow-hides, Goat-skins and Sheep-skins. Coloured Japanned Skins various. 4. Dyed Leather—Dyed Morocco (*i. e.* Goat-Skins), and Roan (*i. e.* Sheep-skins), (for Furniture and Coach purposes). Dyed Morocco and Roan (for Shoe purposes). Dyed Morocco, Roan, Skiver, and Calf (for Bookbinding and Pocket-books, &c). Striped Seal-skin, Cape Sheep-skins, Sheep, Goat, and Horse Hide, (for Shoe-binding, &c.) 5. Oil Leather—Buck, Doe, Calf, Lambs, and Sheep-skins, Ox and Cow-hides (finished natural colour). Buck, Doe, Calf, Lamb, Sheep-skins (dyed or coloured). 6. White or Alum Leather. Alumed Horse-hides, Calf-skins. Sheep and Lamb-skins (stained white). Lamb-skins coloured. Kid-skins, Lamb skins, and Sheep-skins (White and Dyed, for Gloves). Kid-skins, Calf-skins, and Sheep-skins (for Shoes). Varieties. Gaiter Leather. 7. Sheep and Skin Rugs. Sheep and Lamb, Brown, Coloured, and White Rugs. Sheep Rugs for Cavalry Saddles. Angola Goat, Coloured and White. Various Wild Animal Skins for Rugs. 8. Parchment and Vellum. Sheep-skin Parchment for Deeds, Bookbinding, White and Coloured Vellum, White and Coloured, for Bookbinding, Painting, Tambourines, Drum-heads, and Gunpowder-sieves.

B. Saddlery and Harness.

1. Harness; Carriage, Gigs, Carts. 2. Saddlery. 3. Whips.

C. Miscellaneous.

1. Leather Manufacture, such as Bellows, &c. 2. Braces, Webbing-belts, &c.

D. Skins and Fur.

1. Sable and Martin. Russian or Siberian Sable. Hudson's Bay Martin or Sable next in repute and value. The North American or Canadian. Baum or Wood Martin, a native of the Forests of Germany, &c. Stone Martin, living in rocks, old ruined castles, buildings, &c. English Martin. Dyed Sable and Martin. (All as manufactured for Muffs, Tippets, Trimmings, Cuffs, &c.) 2. Otter. Nootka Sound, or Sea Otter. Hudson's Bay and North American Otter. European Otter. Pulled-dyed Otter. (All as used in China for Royal robes, and by the Russians, Chinese, Greeks, and Persians, for Caps, &c.) 3. Fox. Hudson's Bay and North American Black and Silver Fox. Blue Fox. White Fox. Red Fox. Cross Fox. Grey Fox. Kitt Fox. European Red Fox. (All as used abroad for Dresses, and in this country for Coat linings, Carriage Wrappers, Ottomans, Foot Muffs, &c. 4. Bear. Black Bear of Hudson's Bay and North America. Brown, or Isabella. Grey, or Isabella. European Grey and Black Bear. Polar or White Bear. (All used for Army clothing and Accoutrements, and for Hearth-rugs and Sleigh coverings.) 5. Beaver. Beaver from Hudson's Bay and North America. Manufactured and Dyed. (As made into Muffs, Tippets, Cuffs, and other articles of Apparel.) 6. Swan. Swan Skin. Swansdown Skin. Swan Feathers. Swan Quills. (All for Boas, Trimmings, Puffs, &c.) 7. Goose. Goose Skin. Goose Down. (Used as Swansdown.) 8. Mink. North American and Hudson's Bay Mink; as used for Muffs, Tippets, Cuffs, &c. 9. Buffalo for Sleigh Coverings, Open Carriages, and for Railway purposes. 10. Hudson's Bay and North American Skins. Lynx. Lynxcat. Dyed Lynx. Raccoon. Wolf. Fisher. Wolverin. (As used in America, when dyed, for Muffs and Tippets, and in the undyed state by the Chinese, Greeks, and Persians. The Raccoon as linings of Shakos and Coats in Russia and Germany.) 11. Ermine or Weasel tribe. Ermine. Weasel. Polecat or Fitch. Russian Fitch. Dyed Fitch. Kolinski and dyed Kolinski. Kolrosk and dyed Kolrosk. (For general purposes of Ladies' Apparel.) 12. Seal. South Georgia, Shetland, and Falkland Isles. Lomar's Island and Cape. The Plucked and Manufactured Seal. Seal when dyed. The Greenland and Newfoundland Hair Seals. The Labrador Spotted and Silver Seal. The same in its dyed state. (For Men's Coats and Ladies' Dresses, Muffs, Capes, Cuffs, Caps, Waistcoats, Shoes, Boots, &c.) 13. Musquash, or large North American Rat, for Ladies' wear, as for Muffs, Boas, &c. Hamster. Opossum. Perewiazka. (As for Muffs, Tippets, Linings, Cuffs, &c.) 14. Hare and Rabbit. White Hare from Russia and the Polar Regions. European or Grey Hare. Hudson's Bay and North American Rabbit. English Rabbit. Flemish Rabbit. Silver Grey Rabbit. White Polish Rabbit. Black and Blue Rabbit. Australian Rabbit. Dyed Rabbit. (Muffs, Tippets, Linings, Cuffs, &c.) 15. Lamb, &c. Grey Russian Crimea Lamb. Black Ukraine Lamb. Black Astrachan Lamb. Persian Grey Lamb. Persian Black Lamb. Hungarian Lamb. Spanish Lamb. English Lamb. (For general purposes of Dress.) 16. Squirrel. Black Russian. Blue Siberian. Kazan Siberian. American Squirrel. English Squirrel. Indian Striped Squirrel. Flying Squirrel. Dyed Squirrel. (For Ladies' wear, and for Muffs, Tippets, Cuffs, Linings, Trimmings, &c.) 17. Chinchilla. Africa Chinchilla Buenos Ayres Chinchilla. Lima or bastard Chinchilla. (As made into various Articles of Ladies' Dress.) 18. Cat. Dutch Cat or Jennet. European Cat. Wild Cat. African Cat. (For Coat Linings, Sleigh Coverings, Travelling Bags, &c.) 19. Grebe. Eider Duck. Penguin. (For Ladies' use.) 20. Tartar Foal. Angora Goat. Dyed Goat. (Various purposes.) 21. Skins from the Tropics. Lion. Royal Tiger. Cape Tiger. Leopard. Panther. Zebra. Antelope. Black Monkey. Ant Eater. (Mounted for Ornamental purposes

Localities of Exhibition.

A. 1, 2. Bermondsey, Liverpool, Bristol, Cork, Edinburgh, Falmouth; 3. Bermondsey, Birmingham, Leeds, Edinburgh; 4. Bermondsey, Manchester, Leeds; 5. Carshalton, Surrey, Chelmsford, Cambridge, Exeter; 6. Bermondsey, Worcester, Yeovil, Dolgelly, Edinburgh; 7. Bermondsey, Acton, Hertford, Street, Somersetshire, Knaresborough; 8. Camberwell, Walworth, Stourbridge, Cambridge, Bristol. B. London, &c. C. London, Birmingham, &c. D. Chiefly London.

and for Furniture.) Miscellaneous—Moose Deer. Deer. Roe Buck. Badger; the hair of the European Badger as used for shaving brushes, &c. Mole, as made into articles of Ladies' apparel.

E. FEATHERS.

1. Ostrich. Aleppo. Magador. Alexandria. Senegal. Cape. Algoa Bay. Dyed. (As worn in Plumes on Court occasions, by Knights of various Orders and for Military purposes, also in their application to general Dress for Ladies and for Funeral Plumes.) 2. Marabouts. Marabout Stork. Adjutant. Paddy or Rice Bird. White, Grey and Dyed. (As Plumes for Head Dresses, Bonnets, Trimmings for Dresses, Muffs, Tippets, and Fans, and as used with Gold, Silver or Pearls.) 3. Rhea. Long Flossy. Short Flossy. Brown. (The Feathers known by the Plumassiers as "Vulture's," and used for Ladies' wear, made up into fanciful forms, and for military purposes in America; the common sorts made into dusting brooms.) 4. Osprey. Large. Small Egrett. (The Feathers of the small Egrett, as used for Ladies only. Those of the large Osprey for Ladies, and the Feathers of the back, as used for Military Plumes for the Hussar Regiments.) 5. Emu. (The Feathers varying in shades, as used in their natural colour for Ladies' Bonnets, and dyed darker colours and black.) 6. Birds of Paradise. The Large Emerald. The Small Emerald. The King Bird. (The Birds, as worn by persons of rank in the East, also by Ladies in Europe and America, arranged as a Bird.) 7. Heron. The Heron. The White-bellied Darter. (The Feathers of the head and breast of the *Ardrea cinerea*, as used for Ladies, and by Knights at their installation. Those from the back of the *Plotus anhinga*, as used in Europe by Ladies, and in the Eastern Countries by Princes and persons of Rank.) 8. Ibis. (The Feathers of their natural scarlet colour, as made into Wreaths for the Head.) Swan. (For Ladies and Bonnets and Military Plumes.) Turkey. (The Down of these Birds as used for Ladies' Plumes and Trimmings.) Cock. (The Feathers of the neck, back, and tail made into Plumes for Ladies' and Childrens' Hats and Military Plumes.) Peacocks. (For Plumes and Screens.) Argus Pheasant. (The Feathers marked with eyes, as used, the small for Plumes, the large for Tiaras for the head.) Common Pheasant. (Made into Trimming.) Eagle. (The Feathers forming the wing of this Bird as used for the Highland Bonnet.) 9. Miscellaneous. (The Feathers of the Jay, Duck, Grebe, and Tucan, as also several Birds from the Tropics, in their applications to Ladies' dresses.)

Localities of Exhibition.
E. Chiefly London.

F. HAIR.

1. Hair as a substitute for Human Hair, as Wigs, Curls, Fronts, &c. 2. Ornaments in Hair, as Plumes, Bracelets, Guards, &c. (See also XXIII. C.) 3. Hair Cloth for the purposes of Furniture. 4. Hair for Miscellaneous purposes, as for stuffing Furniture.

CLASS XVII. *Paper and Stationery, Printing and Bookbinding.*

A. PAPER IN THE RAW STATE AS IT LEAVES THE MILL.

1. Brown Paper and Packing Papers. 2. Millboards and Glazed Boards for pressing. 3. Printing Papers. 4. Drawing Papers. 5. Writing Papers. 6. Tissue Papers, white and tinted. 7. Papers tinted in the Pulp. 8. Tracing Papers, made so in the Pulp. 9. Papers ornamented in the Water-mark. 10. Cartridge Paper.

B. ARTICLES OF STATIONERY.

1. Envelopes, plain and ornamental. 2. Embossed and Lace Papers. 3. Printed Fancy Papers and Surface-coloured Papers, Printed and Embossed Ornaments. 4. Wedding Stationary (Cards, Papers, and Envelopes). 5. Mourning Stationery (Cards, Papers, and Envelopes). 6. Specimens of Ornamenting, Glazing, and Packeting Writing Papers. 7. Sealing-wax, and Wafers. 8. Pens. 9. Small Wares for Stationery. 10. Tracing Paper, made transparent by Varnishes. 11. Inks of all kinds.

C. PASTEBOARDS, CARDS, &c.

1. Playing Cards. 2. Message Cards, plain and ornamental. 3. Drawing Boards. 4. Mounting Boards, plain and ornamental. 5. Pasteboard and Cardboard.

D. PAPER AND SCALEBOARD BOXES, CARTONS (CARTONNERIE).

All kinds of Boxes and Cases made of Pasteboard and Paper (not being Papier Maché), plain or ornamented.

E. PRINTING (NOT INCLUDING FINE ART PRINTING),

1. Type-printing generally. 2. Printing Inks and Varnishes.

F. BOOKBINDING, &c.

1. Binding in Cloth; 2. in Vellum; 3. in Leather; 4. in Velvet; 5. in Wood, Papier-maché, or Metal. 6. Albums, Scrap-books, Portfolios, Music-books, Manuscript-books, Memorandum-books. 7. Ledgers and Account-books. 8. Blotting-cases, Desks, Cabinets, Pocket-books, Card-cases, Note-cases, &c. 9. Porte-monnaie, and other Articles of a similar nature.

Localities of Exhibition.
A. Lancashire, Kent, Berkshire, Derbyshire, Hertfordshire, and various parts of Scotland, and Ireland. B. London, Edinburgh, Birmingham, &c. C. London and Westminster. D. London, Nottingham. E. 1. All parts of the United Kingdom; 2. London and Birmingham. F. 1—5, London, Oxford, Birmingham, &c.; 6—9, London, Birmingham, Sheffield.

CLASS XVIII. *Woven, Spun, Felted, and Laid Fabrics, when shown as specimens of Printing or Dyeing.*

A. PRINTING OR DYEING OF WOOLLENS, OR ANY MIXED SUBSTANCES, AS MOUSSELINE DE SOIE, DE LAINE, OR ALPACA MIXTURE.

1. Mousseline de Laine, de Soie, &c.—Made of all Wool; Cotton and Wool. Cashmere—Made of all Wool; Cotton and Wool. Barège—Made of Silk and Wool; Cotton and Wool; all Wool; Cotton, Silk, and Wool. Balzarine, plain and figured—Made of Cotton and Wool; Silk and Wool; Cotton, Silk, and Wool. 2. Printed or Dyed Cotton or Silk Wa ps, afterwards woven,

Localities of Exhibition.
A. 1. Manchester, Glasgow, Crayford, Kent, Bradford, Leeds, Huddersfield, Stroud, Wiltshire, &c. A. 2, 3. Manchester, Mitcham, Surrey, Crayford, Kent.

known as Chiné. 3. Printed Woollen Table-covers; Japanned ditto. 4. Printed and Dyed Silks—India Corahs in the Grey; dyed and printed in England. India Bandannas (tied and dyed in India); Choppahs (printed in India). British Corahs in the Grey; dyed and printed. British Twills in the Grey; dyed and printed. British Spun Silks, printed. British Cambrics, printed and dyed. British Spun Silk Dresses, dyed and printed. British Corah Dresses, printed. India Corah Dresses, printed. Printed China Crape Shawls.

B. Printed Calicoes, Cambrics, Muslins, Velvet and Velveteens—

1. Cottons printed by Machines only; by Block only; and partly by Block and Machinery. Turkey-red, printed or dyed; Mules. Muslins printed by Machinery; by Block; partly by Block and Machine. Prints and Furniture by Machine only; by Block only; partly by Block and Machine. 2. Handkerchiefs for the pocket, head, neck, and shoulders. Single Colours, blue ground, &c. Assorted Colours, fast and loose. Turkey-red Bandannas printed; discharged; Chintz pattern. Printed Border Handkerchiefs. Imitation Cambric; Fancy Muslin. Imitation Java batticked Handkerchiefs. Printed Aprons. 3. Printed Shawls and Dresses. Shawls, assorted Colours, and Turkey-red, or purple, part with fringe, part without. Java Sarongs batticked; Turkey-red. Java Slendrongs, Turkey-red and batticked. Malay Chindey or Imitation. Bombay Patolio. Siam Shawls. Scarfs. Dresses.

C. Dyed Cotton Goods.

Cambrics and Madapolones, assorted Colours; and in Turkey-red. Imitation blue Morries and Basstas. Long Cloths of all kinds. Mull and Book Muslin of all kinds. Cotton Drills (blue). Velvet. Velveteens.

D. Dyed Linen Goods.

Printed Linens. Cambric Handkerchiefs. Lawn Shirt Fronts. Lawn Handkerchiefs.

E. Dyeing or Printing of Leather, Hair, Fur, &c.

Localities of Exhibition.

A. 4. West Ham Abbey, Crayford, Mitcham, Langley, near Macclesfield, &c. B. 1. Manchester, Glasgow, Carlisle.

B. 3. Manchester, Glasgow, Paisley, Mitcham, Crayford. C Manchester, Glasgow, Northallerton, Carlisle. D. Manchester, Belfast, Crayford, Bermondsey.

Class XIX. *Tapestry, including Carpets and Floor-cloths, Lace, Embroidery, Fancy and Industrial Work.*

A. Tapestry.

1. Carpets of all kinds in which the Pattern is produced by Weaving or by the Hand, in the manner of Tapestry proper, including Hall Carpets, Rugs, Stair, &c.

a. Axminster Carpets, Flax or Jute, Chain, Woollen, or Worsted Pile, worked by hand. *b.* Table and Chair Covers, &c., worked in the same way. *c.* Patent Axminster Carpets, manufactured at Glasgow, made firstly as a woven Fringe, and that adapted afterwards to a thick Flax surface. *d.* Patent Tapestry Carpet. Pattern printed in warp, any number of colours used; Table-covers, Curtains, &c., made in the same way. *e.* Patent Tapestry Rugs, velvet pile surface with a thick weft shoot of cotton, flax, or other material. *f.* Brussels and Velvet Pile Carpet. *g.* Tapestry Brussels Carpets, called Moquette, of a fine quality. *h.* Kidderminster and Venetian Carpet. *i.* Patent Mosaic Tapestry and Rugs, where the cut Wool is fixed to a ground by caoutchouc, &c. *j.* Printed Felt Carpet, Plain and Printed Druggets, Printed and Embossed Cloth for Table-covers and Curtains. *k.* Patent Printed Carpets, with Terry Pile Surface; the same Moquette for Curtains or Furniture. *l.* Cloth Embroidered by Machinery for Table-covers or Curtains.

2. Matting of Hemp, Cocoa-nut Fibre, Straw, Reeds, and Grasses, for Floors and Walls.

3. Oil-cloth for Floor or Table, whether painted or printed.

4. Woven or embroidered Crochet and Net Work.

5. Counterpanes and Quilts for Bed Covers; Quilting and Dimity for Bed Room Hanging.

6. Ornamental Tapestry of Silk, Wool, Linen, Mohair, Cotton, or of these materials mingled together, or with Metal Wires, whether woven in the Loom or of any kind of Needle-work, but of patterns having so much artistic excellence as to entitle them to be exhibited in Section XXX. as Works of Fine Art.

B. Lace.

1. Pillow Lace, the article or fabric being wholly made by hand (known as Valenciennes, Mechlin, Honiton, Buckingham;) or Guipure made by the Crochet Needle, and Silk Lace, called "Blonde" when white, and Chantilly, Puy, Grammont, and Black Buckinghamshire when black. 2. Lace, the ground being Machine-wrought, the Ornamentation made on the Pillow and afterwards applied to the Ground (known as Brussels, Honiton, or appliquée Lace). 3. Machine-made Nets and Quillings, wholly Plain, whether Warp or Bobbin (known as Bobbin Net, Tulles, Blondes, Cambraie, Mechlins, Malines, Brussells, Alençon, &c.). 4. Lace, the Ground being wholly made by Machine; partly Ornamented by Machine and partly by Hand; or wholly Ornamented by Hand, whether Tamboured, Needle-Embroidered, or Darned. 5. Lace actually Wrought and Ornamented by Machinery; comprising Trimming Laces of every description, Veils, Falls, Scarfs, Shawls, Lappets, Curtains, &c.

C. Sewed and Tamboured Muslins.

Ladies' Collars, Cuffs, &c. Children's Robes. Handkerchiefs. Trimmings and Insertions. Vest Pieces. Shirt Fronts. Mantles. Dresses. Curtains, &c.

D. Embroidery.

1. Gold and Silver and Glass. 2. Silk, as Shawls, Dresses, Mantles, Table Covers, and Curtains, &c.

Localities of Exhibition.

A. 1. London, Kidderminster, Wilton, Glasgow; *a.* Wilton and Mill-bridge; *c.* Glasgow; *d.* Lasswade, Halifax, Kidderminster; *e.* Lasswade and Glasgow; *f.* Kidderminster, Bridgenorth, Stourport, Mill Bridge, Kilmarnock, Durham; *g.* Lasswade; *h.* Kidderminster, Halifax, Mill Bridge, Durham, Kilmarnock, Bannockburn, &c.; *i.* Halifax; *j.* Bury, London; *k.* Rochdale, Macclesfield; *l.* Manchester; 2. Dundee, London, Abingdon; 3. London, Bristol, Bolton.

B. 1. Buckinghamshire, Bedfordshire, Honiton and its neighbourhood, Ireland; 2. Honiton and Buckinghamshire; 3. Nottingham, Derby, Tiverton, Coggleshall, Islington; 4. Nottingham, London, Limerick, Glasgow, and parts of Essex; 5. Nottingham, Isle of Wight. C. Glasgow and Belfast.

3. Berlin Wool, Chair Covers and Fancy Articles for the Drawing Room. 4. Embroidery by Machinery.

E. Fringes, &c.

1. Fringes, Tassels, Gymps, &c., suitable as Trimmings for Upholstery. 2. Ditto, for Dresses and other fine Work.

F. Fancy and Industrial Works.

1. Berlin Wool Work. 2. Needle-work. 3. Miscellaneous Industrial Works.

Localities of Exhibition.

E. 1. London; 2. Derby and London.

Class XX. *Articles of Clothing for Immediate, Personal, or Domestic Use.*

A. Hats, Caps, and Bonnets.

1. Hats, made of Silk, Beaver, or other materials, for Men.
2. Caps, for Men.
3. Bonnets of Straw, Silk or other material.
a. British Chip Bonnet made from the Poplar. *b.* Willow Bonnet. *c.* Brazilian Grass Hats. *d.* Tuscan and Leghorn Plaiting and Bonnets. *e.* Straw Plait Bonnets. *f.* Straw Trimmings and Bonnets. *g.* Horse Hair Trimmings and Bonnets. *h.* Silk and other Bonnets made by Milliners.

B. Hosiery.

1. Cotton. 2. Woollen. 3. Linen. 4. Silk.

C. Gloves.

1. Made of Leather or Skins. 2. Made of any other materials.

D. Boots, Shoes, and Lasts.

1. Made of Leather. 2. Made of other materials.

E. Under Clothing.

1. For Ladies. 2. For Gentlemen.

F. Upper Clothing.

1. For Ladies, including all kinds of Millinery. 2. For Gentlemen, including all kinds of Tailor's-work.

Localities of Exhibition.

A. 1. London, Newcastle-under-Lyne, Manchester, Stockport, Oldham, Bristol; 2. London, Bristol, and other large towns; 3. London, Tring, St. Albans, Halstead, Heddingham, &c. Chesham. Dublin, Dunstable, London, &c. B. Leicester, Nottingham, Perth, Balbriggan, Tewkesbury, Loughborough, Wells, Hawick, Dumfries, Aberdeen, Bala, Kendal.

C. Worcester, Dundee, Yeovil, Woodstock, Limerick, &c. D. Northampton, Stafford, London, Norwich, &c. E. Nottingham, Leicester, Derby, Godalming, Wells, Somerset, Hawick, Dumfries, &c. F. All large towns.

Class XXI. *Cutlery and Edge-tools.*

A. Cutlery, such as Knives and Forks, Pen and Pocket Knives, Razors, Scissors, and Shears.

1. Knives and Forks—Table, Dessert, Carving. Dessert or Fruit, with plated and silver blades. Cake and Melon Carvers, with ditto. Fish Knives and Forks, with ditto. 2. Spring Knives—Pen and Pocket Knives of every description. Hunting and Sportsmen's Knives. 3. Knives of all other descriptions—Paper Knives of all kinds. Desk or Office Knives. Palette Knives. Knives for Hunting and Self-defence, as Couteaux-de-Chasse, Bowie Knives, &c. Knives for Kitchen and Domestic Purposes, as Cook's, Oyster, Onion, Bread and Butter, and Cheese Knives. Knives used in various Trades, as Butchers, Shoemakers, Glaziers, Gardeners, &c. 4. Scissors and Shears—Ladies' Work and Cutting-out Scissors of every description. Nail, Button-hole, Barbers', and Trimming Scissors. Shears used in various Trades, as Tailors, Brush-makers, &c. Garden and Sheep Shears. 5. Razors of all kinds. 6. Miscellaneous—Corkscrews, Button-hooks, Boot-hooks, Nail-nippers, Nail-files, Tweezers, &c.

B. Files and other small Edge Tools, not included in Manufacturing Tools in Section VI.

1. Files and Edge-tools used by Engineers, Smiths, or other Metal Workers;—2. for purposes of Building, by Masons, Bricklayers, and Plasterers;—3. for fine Metal and other work, as for Clock and Watchmakers, Jewellers, Lapidaries, Engravers, and Modellers;—4. for Wood-work, as for Carpenters, Joiners, Cabinet-makers, Coopers, &c.;—5. for Leather or Skins, as for Saddlers, Curriers, Shoemakers, and Bookbinders;—6. Drawing, Artist's, and Engraving Instruments. 7. Files and Edge-tools for other purposes than those specified.

Localities of Exhibition.

A. Sheffield, London, Birmingham.

B. Sheffield, Warrington.

Class XXII. *Iron and General Hardware.*

A. Brass Manufacture.

1. Cabinet and general Brass Foundry, consisting of Hinges, Fastenings, Escutcheons, Bell-pulls, Brassfoundry used in Ships, Knockers, Door-springs, Castors, &c. 2. Plumbers' Brass Foundry Cocks, Valves, Pumps, Water-closets, &c. 3. Stamped Brass Foundry, Cornices, Curtain-bands, Finger-plates, &c. 4. Gas-fittings, Brackets, Chandeliers, Pillars, Gas-burners, and Consumers' Meters, &c. 5. Tubing, plain and ornamental. 6. Metallic Bedsteads, brass and iron. 7. Chandeliers, Lamps, and Candelabra, for Oil, Candles, or Camphine, and Lamp Chains. 8. Railway and Carriage Brassfoundry, and Signal Lamps and Lanterns. 9. Bronze Figures, Busts, and Chimney Ornaments. 10. Bells, House, Church, Ship, Table, &c., and Alarums. 11. Candlesticks, Table and Bedroom. 12. Monumental Brasses and Ecclesiastical Brass-work. 13. Copper and Steel Plates, for Engravers. 14. Miscellaneous.

B. Copper, Zinc, Tin, Pewter, and General Braziery.

1. Kettles, Coal Scuttles, Coppers, Saucepans, Steamers, Plate-warmers, &c. 2. Bronzed Tea and Coffee Urns, Kettles, &c. 3. Tubing—

Localities of Exhibition.

A. Birmingham, London, Dublin.

B. Birmingham, London, Sheffield.

Copper, Tin, Lead, &c. 4. Pewter, German Silver, and Britannia-metal Tea-pots, Basins, Dishes, Spoons, Ladles, Inkstands, &c. 5. Coffin Furniture—Plates, Escutcheons, &c. 6. Zinc Articles generally.

C. Iron Manufacture. (See also I. and V.)

1. Stoves, Grates, Fenders and Fire Irons, Kitchen Ranges, Cooking Apparatus, Smoke-jacks. 2. Warming Apparatus, for Halls and Rooms, Ships, &c., either by Water, Coal, Coke, Wood, Charcoal, or Gas. 3. Shower, Vapour, Air, and Warm-water Baths. 4. Ventilators—Metallic and others. 5. Pipes and Gutters, &c. 6. Locks and Hinges. 7. General Ironmongery. 8. Ice Machines. 9. Knife-cleaning Machines. 10. Letter-copying Machines and Presses. 11. Saddlers' Ironmongery. 12. Hollow Ware, cast and wrought, tinned and enamelled. 13. Spades, Shovels, Pickaxes, Hoes, Rakes, Garden-rollers, &c. (See also J. IX.) 14. Nails, cut, cast, and wrought, in Iron, Copper, and other Metals. 15. Screws and Railway Bolts, &c. 16. Iron Safes, Cash-boxes, fire-proof and otherwise. 17. Horse-shoes. 18. Gates, Railings, Hurdles, and Stable Fittings. 19. Mangles, Washing Machines, &c.

Localities of Exhibition.

C. Sheffield, Birmingham, Wolverhampton, Walsall, West Bromwich, London.

D. Steel Manufacture.

1. Tools and heavy Steel Toys, Hammers, Vices, &c. 2. Steel Ornaments, and light fancy Steel Toys, Brooches, Buckles, &c. 3. Steel Pens and Metallic Pens. 4. Needles, Fish-hooks, and Fishing Tackle.

E. Buttons, &c.

1. Buttons—Metallic, Florentine, Pearl, Bone, &c. 2. Metal Boxes, Watch Boxes, &c.

F. Wire Work, &c.

1. Wire Gauze, and Window Blinds, Fencing, Pheasantry, Birdcages, &c. 2. Wire—Iron, Brass, Steel, and Copper. 3. Pins—white and black. 4. Hooks and Eyes. 5. Metallic Wire Baskets. 6. Wire Rope.

Localities of Exhibition.

D. Birmingham, Redditch. E. Birmingham, F. Birmingham.

Class XXIII. *Working in Precious Metals and in their imitations; Jewellery, and all Articles of Virtu and Luxury not included in the other Classes.*

A. Communion Services.

As Altar-dishes, Flagons, Chalices, Patens, Plates, &c.

B. Articles of Gold and Silver Plate, for Decorative Purposes and Presentation Pieces.

1. Racing Prizes, Testimonials, allegorical, historical, and emblematic Groups and Compositions, Shields, Centre Pieces, Vases, Tazzas, Ewers, Salvers, Candelabra, &c. 2. The same Articles made in hammered or repoussé metal.

C. Smaller Articles for more general Domestic Use.

1. For the Dinner Table; as Smaller Candelabra with branches, Candlesticks, Centre Pieces, Soup and Sauce Tureens, Covered Dishes, Smaller Mounted Dishes, Flat Dishes, Flower-stands and Epergnes, Dessert Services, Table and Dessert Knives, Spoons and Forks, Salvers, Bread and Cake Baskets, Claret Jugs, Wine Coolers, Cruet Frames, Mustard Pots, Salts, &c. 2. Breakfast and Tea-table Service; as Tea and Coffee Urns and Kettles, Tea and Coffee Pots and Stands, Sugar Basins, Milk and Cream Jugs, Ewers and Basins, Toast Racks, &c. 3. Dressing and Library Table and Travelling Utensils; as Inkstands and Writing Appendages, Dressing Cases and Instruments, &c. 4. Miscellaneous; as Watch and Clock Cases, Toys, Pencil Cases, Seals and Keys, Filagree Baskets and Ornaments.

D. Electro-plated Goods of all descriptions, comprehending all that can be executed in Silver and other Metals.

E. Sheffield and other plated Goods.

1. Centre and Side covered Dishes and Warmers, Soup Tureens, Cruet Frames, Liqueur Frames, Pickle ditto, Candlesticks and Branches, Candelabra, Bread and Cake Baskets, Snuffers and Trays, Tea and Coffee Services, Tea Trays, Hand Waiters, Claret Jugs, Decanter Stands, Sugar Stands, Flower Stands, Nut Crackers, Grape Scissors, Mustard Pots, &c. &c.

Localities of Exhibition.

B. London, &c. C. London, Birmingham, Sheffield, Edinburgh, &c. D. Birmingham, London, Sheffield. E. Sheffield, Birmingham, London, &c.

F. Gilt and Ormolu Work.

1. Gilt by the Electro process. 2. Gilt by amalgamation, or "Water Gilding." 3. Imitation Jewellery and Toys.

G. Jewellery.

1. Works exhibiting the Precious Stones and Pearls, as Diamonds, Rubies, Sapphires, Emeralds, Opals, Turquois; and the manner of setting them in Crowns, Coronets, Stars, Orders, Tiaras, Head Ornaments, Bouquets, Necklaces, Bracelets, and Armlets, Presentation Snuff Boxes, Brooches, Ear Pendants, Medallions, Studs, and Buttons. 2. Ornaments similar to those of the former class, in which are exhibited the setting of the Inferior Stones, as Amethysts, Topazes, Carbuncles, Aquamarines, Jacynths, Crysophrases, Carnelians, Onyxes, whether plain or set, Cameos or Intaglios, Engraved Shells, &c. &c. 3. Ornaments made of Gold, whether plain or enamelled; as Bracelets, Brooches, Necklaces, Ear-rings, Pins, Waist-Buckles, Chains, Buckles, Studs, Chatelaines, &c. &c. &c 4. Jewellery by imitations of Precious and other Stones. 5. Ornaments worked in Ivory, Jet, Horn, Hair, and other materials of which the Precious Stones or Metals do not form the principal feature.

H. Ornaments and Toys worked in Iron, Steel, and other Metals, which are neither Precious Metals nor Imitations of them, as Chatelaines of Steel, Chains of Steel, Sword-hilts, Cut Steel Shoe and Knee Buckles, Berlin Iron Ornaments, Chains, Necklaces, Bracelets, &c.

Localities of Exhibition.

F. London, Birmingham, &c. G. London, Birmingham, Edinburgh, Dublin, &c. H. London, Birmingham, Sheffield, &c.

I. Enamelling and Damascene Work.

1. Enamelling of subjects on Gold and Precious Metals. (Except when shown in the Section of Fine Arts.) 2. Damascene Work, or insertion of one Metal in another, not included in the above-named Classes, as forming a minor ingredient in some more important species of Manufactures.

J. Articles of Use or Curiosity not included in the previous enumeration.

Class XXIV. *Glass.*

A. Window Glass, including Sheet Glass, Crown Glass, and Coloured Sheet Glass.

1. Crown. 2. Sheet. 3. Blown Plate Glass, silvered and unsilvered. 4. Coloured Sheet, Pot Metal, or flashed. 5. Glass Ventilators. 6. Glass Shades, round, oval and square.

B. Painted and other kinds of Ornamented Window Glass.

1. Enamelled, Embossed, Etched, painted white, or coloured Window Glass. 2. Painted and Leaded Windows.

C. Cast Plate Glass.

1. Rough Plate. 2. Ground and Polished, silvered and unsilvered. 3. Pressed Plate. 4. Rolled Plate, white and coloured.

D. Bottle-glass.

1. Ordinary Bottle-glass, including Moulded Bottles. 2. Medicinal Bottle-glass, including Phials, &c., blown and moulded, of all kinds and shapes. 3. White Bottle-glass, Blown, Pressed, and Moulded Bottles. 4. Water-pipes and Tubing.

Localities of Exhibition.

A. Birmingham, Bristol, St. Helens, Shields, Sunderland, Newcastle, London. B. Edinburgh, Glasgow, Sunderland, Newcastle, St. Helens, Shrewsbury, York, Warwick, London, Birmingham. C. London, Birmingham, St. Helens, Shields, Sutton, Ravenhead, Sunderland. D. Bristol, Sunderland, Shields, Newcastle, Castle Ford, St. Helens, Glasgow, Greenock, Dudley, Bristol.

E. Glass for Chemical and Philosophical Apparatus.

1. Glass for Matras, Retorts, and other kinds of Chemical and Philosophical Apparatus. 2. Water-pipes and Tubing.

F. Flint-glass or Crystal, with or without Lead, white, coloured, and ornamented, for Table Vases, &c.

1. Blown. 2. Moulded and Pressed. 3. Cut and Engraved. 4. Reticulated and spun with a variety of colours, incrusted, flashed, enamelled of all colours, opalescent, imitation of Alabaster, gilt, platinised, silvered, &c. 5. Glass Mosaic, Millefiori, Aventurine, and Venetian Glass Weights, &c. 6. Beads, imitation Pearls, &c. 7. Chandeliers, Candlesticks, and all Glass Apparatus for Lamps, Candlesticks, Gerandoles, Wall Brackets, with or without drops, &c.

G. Optical Glass, Flint and Crown.

1. Rough Discs of Flint and Crown, to make Lenses for Telescopes, Microscopes, Daguerreotype and Calotype Apparatus, &c. 2. Flint and Crown, blown or cast in plates for the Optician. 3. Thin Glass for Microscope. 4. Refractive Apparatus, Prismatic Lenses for Light-houses (see also Class J).

Localities of Exhibition.

E. Stourbridge, Birmingham, London, Newcastle. F. London, Stourbridge, Birmingham, Newcastle, Dudley, Edinburgh, Glasgow, Greenock. G. London, Birmingham, Newcastle, Shields.

Class XXV. *Ceramic Manufactures.—Porcelain, Earthenware. &c.*

A. Porcelain, Hard.

1. Chinese. 2. Japanese. 3. Continental, as Berlin, Meissen, &c.

B. Statuary Porcelain.

1. Statuary. 2. Parian. 3. Carrara.

C. Tender Porcelain.

1. English Porcelain, soft or tender. 2. French, with Siliceous body.

D. Stoneware, Glazed and Unglazed.

1. Ironstone, or Stone China, glazed. 2. White Stone body; 3. Coloured body, Jasper; 4. Egyptian black, 5. Red, 6. Cane, 7. Drab (all unglazed). 8. Brownware, with salt glaze. (The Lambeth, Chesterfield, and Beauvais manufactures are included in this class.) 9. Chemical utensils. (These are made both in Stoneware and Hard Porcelain.)

E. Earthenware.

1. White body for Printing, Painting, or Enamelling in different Colours. 2. Common Cream colour. 3. Green glazed ware. 4. Rockingham, 5. Delph, 6. Majolica, 7. Mocha and Dipt wares. 8. Common lead glazed ditto, for utensils. 9. Coloured body, Turquoise, 10. Drab, 11. Olive, 12. Buff, 13. Cottage brown.

F. Terra Cotta.

1. Vases and Garden Pots. 2. Ornaments for Architecture. 3. Encaustic or Inlaid Tiles. 4. Tesseræ of various colours, compressed from powdered clay. 5. Superior Plain Tiles for Pavements; 6. Bricks; 7. Roofing Tiles (all from powdered clay). 8. Chimney Pipes. 9. Common Bricks. 10. Common Roofing Tiles, &c.

G. Ornamented or Decorated.

1. Ornamented on *Bisque* — Painted by hand. Printed and Transferred in various colours. 2. Ornamented *on the glaze* — Painted by hand. Printed by the press. Printed by hand. Gold, Silver, and Steel Lustre. Enamelling in various colours. Gilding.

H. Productions for Architectural Purposes.

Localities of Exhibition.

A. Stoke-upon-Trent. B. Staffordshire Potteries, Coalport. C. Staffordshire Potteries, Coalport, Worcester. D. 1—7. Staffordshire Potteries; 8. Lambeth and Vauxhall. E. Staffordshire Potteries, Newcastle-upon-Tyne, Glasgow, Sunderland, Bristol, Swansea, Stockton-upon-Tees. F. 1—3. Staffordshire Potteries, and other places in the United Kingdom; 4. Stoke-upon-Trent. G. All the various localities mentioned above.

Class XXVI. *Decoration Furniture and Upholstery, including Paper Hangings, Papier Maché, and Japanned Goods.*

A. Decoration generally, including Ecclesiastical Decoration.

1. Ecclesiastical Decoration generally. 2. Ornamental coloured Decoration, as executed by hand. 3. Imitations of Woods, Marbles, &c., executed by hand. 4. Relievo Decoration, mechanically produced.

Localities of Exhibition.

A. London, Edinburgh, Glasgow, Birmingham, &c.

B. Furniture and Upholstery.

1. Cabinet Work, plain. 2. Cabinet Work, carved or ornamental. 3. Marqueterie, in-laid Work, in Woods, &c. 4. Buhl or Metallic in-laid Work. 5. Chairs, Sofas, and Beds, and general Upholstery.

C. Paper Hangings.

1. Damask patterns. 2. Flower patterns. 3. Flock and Metal Papers. 4. Decorative Paper-hangings by Block-work; 5. by any other process. 6. Machine-printed Paper-hangings.

Localities of Exhibition.

B. London, and most provincial towns. C. London, and Manchester.

D. Papier Maché, Japanned Goods, Pearl, and Tortoiseshell Work.

1. Papier Maché, japanned, inlaid, and decorated. 2. Papier Maché (not japanned), produced in ornamental forms for decoration. 3. Japanned Goods in Iron, &c. 4. Pearl and Tortoiseshell Work.

Localities of Exhibition.

D. London, Birmingham, Wolverhampton, Bilston

Class XXVII. *Manufactures in Mineral Substances used for Building or Decorations, as in Marble, Slate, Porphyries, Cements, Artificial Stones, &c.*

A. Manufactures in Common Stones.

1. For building, and constructions not strictly decorative. 2. For decorative purposes.

B. Manufactures in Slate.

1. For Construction. 2. For Decoration.

C Manufactures in Cement and Artificial Stone.

D. Manufactures in Marbles, Granites, Porphyries, Alabaster, Spar, &c., for useful or ornamental Purposes.

Localities of Exhibition.

B. Wales, Devon, London. C. London, Staffordshire, Bath, Southampton, Ipswich, Dorsetshire, Ireland. D. Derbyshire, Devonshire, Cornwall, Aberdeen, &c.

1. For construction and external decoration. 2. For internal decoration (not furniture), as Chimney-pieces, &c. 3. For articles of furniture, as Tables, &c. 4. For purposes of mere ornament.

E. Inlaid Work in Stone, Marble, and other Mineral Substances.

F. Ornamental Work in Plaster, Composition, Scagliola, Imitation Marble, &c.

G. Combinations of Iron and other Metals with Glass and other Substances for various useful purposes.

1. For architectural purposes. 2. For Miscellaneous purposes.

Localities of Exhibition.

F. London, Derbyshire. G. London, Birmingham, &c.

Class XXVIII. *Manufactures from Animal and Vegetable Substances, not being Woven, Felted, or included in other Sections.*

A. Manufactures from Caoutchouc.

1. Impermeable articles — Boots. Holdsworth's Life Preservers. Captain Smith's ditto. Hydrostatic and Air Beds. Water and Air Cushions. Gas Bags. Printers' Blankets. Cloaks, Capes, Coats, Paletots, &c. Boots and Shoes. Over Shoes, or Goloshes. Fishing and Deck Boots. Ship Sheets. Bellows. Air-pump Valves for Steam Engines. Sponge Baths and Bags. Prepared Water and Air-proof Textures of every description. 2. Elastic Articles—Railway and other Carriage Springs. Railway Buffers. Valve Canvas. Knee Caps. Surgical Bottles. Pump-buckets and Valves. Bands and Rings for Letters and Packages. Writing Tablets. Trouser Straps. Gussets for Boots. Vest Backs. Washers for Flange and Socket Joints. Driving Bands for Machinery. Railway Felt. Wheel Tires. E. Smith's Torsion Springs for Window-blinds, and Shades. Door Springs. Dr. Bell's Sewer and Sink Valves. Hodges's Projectile and Lifting Straps. Air-pump Valves. Elastic Webbing. Cricket Gloves and Balls. Stoppers for Decanters, Bottles, Jars, and other vessels. 3. Articles in Caoutchouc—Moulded, Embossed, Coloured, and Printed. Bas Reliefs. Bags. Maps, printed on Caoutchouc. Sheets in Colour. Embossed and Printed Ornaments. Garters, Bracelets, &c., Embossed, Coloured or Printed. Bottles, Embossed and in Colours. Embossed Sheets for Seats and other purposes. Vulcanized Articles combined with Metal — such as Decanter Stoppers, Inkstands, Cocks and Taps for Fluids, Hinges, Locks, and Bolts, Wheel Tires, Plugs for Cisterns, Linings of Vessels, &c.

B. Manufactures from Gutta Percha.

1. For Waterproofing Purposes. 2. For Agricultural Uses, as Tubing for Manure, &c. 3. For Maritime Purposes, as Speaking Trumpets, Life Buoys, Life Boats, Cords, Tiller Ropes, &c. 4. Decorative Uses, as Ornamental Mouldings, Brackets, Medallions, Picture Frames, &c. 5. Surgical. Electrical, and Chemical Uses, as Dissolved Gutta Percha for wounds, Stethoscopes, Splints, Ear Trumpets, &c., Carboys, Funnels, Acid Vessels, &c., Covering of Telegraph Wire, Insulating Stools, &c. 6. Domestic and Miscellaneous Uses, as Soles for Shoes, Linings of Cisterns, Conveyance of Water and Gas, Hearing Apparatus, &c.

C. Manufactures from Ivory, Tortoiseshell, Shells, Bone, Horn, Bristles, and Vegetable Ivory.

D. General Manufactures from Wood (not being Furniture).

1. Turnery. 2. Carving, &c. 3. Coopers' Work of all kinds. 4. Basket and Wicker-work. 5. Miscellaneous Wood-work.

E. Manufactures from Straw, Grass, and other similar Materials.

F. Miscellaneous Manufactures from Animal and Vegetable Substances.

Class XXIX. *Miscellaneous Manufactures, and Small Wares.*

A. Perfumery and Soap.

B. Articles for Personal Use, as Writing Desks, Dressing Cases, Workboxes, when not exhibited in connexion with Precious Metals (XXIII.), and Travelling Gear generally.

C. Artificial Flowers.

D. Candles, and other means of giving Light.

E. Confectionary of all kinds.

F. Beads and Toys, when not of Hardware, Fans, &c.

G. Umbrellas, Parasols, Walking-sticks, &c.

H. Fishing tackle of all kinds, Archery.

I. Games of all kinds.

J. Other Miscellaneous Manufactures.

FINE ARTS.

(So far as they come within the limitations of the Exhibition.)

Class XXX. *Sculpture, Models, and Plastic Art.*

A. Sculpture as a Fine Art.

1. In Metals simple, as Gold, Silver, Copper, Iron, Zinc, Lead, &c. 2. In Metals compound, as Bronze, Electrum, &c. 3. In Minerals simple, as Marble, Stone, Gems, Clay, &c. 4. In elaborate Mineral Materials, as Glass, Porcelain, &c. 5. In Woods and other Vegetable Substances. 6. In Animal Substances, as Ivory, Bone, Shells, Shell Cameos.

B. Works in Die-sinking, Intaglios.

1. Coins, Medals, and Models of a Medallic character in any material. 2. Impressions struck from Dies for ornamental purposes. 3. Gems, either in Cameo or in Intaglio, Shell Cameos. 4. Seals, &c.

C. Architectural Decorations.

1. Integral, in Relief, Colour, &c. 2. Adventitious, as Stained Glass, Tapestry, &c.

D. Mosaics and Inlaid Works.

1. In Stone. 2. In Tiles. 3. In Vitrified Materials 4. In Wood. 5. In Metal.

E. Enamels.

1. On Metals. 2. On China. 3. On Glass.

F. Materials and Processes applicable to the Fine Arts generally, including Fine Art Printing, Printing in Colour, &c. &c.

1. Encaustic Painting and Fresco. 2. Ornamental Printing, Chromo-typography, Gold-Illuminated Typography, Typography combined or uncombined with Embossing. 3. Lithography Black, Chromo-lithography, Gold-Illuminated Lithography, Lithography combined or uncombined with Embossing. 4. Zincography or other modes of Printing.

G. Models.

1. In Architecture. 2. In Topography. 3. In Anatomy.

Section VIII.—The Catalogue.

There is perhaps no literary undertaking more wonderful than the production of a daily newspaper such as the *Times*. This paper, with its Supplement, consists of 72 columns, or 17,500 lines, made up of upwards of a million pieces of type. To produce 30,000 or 40,000 copies of such a work every day is a mechanical marvel, which becomes indeed impressive when we consider how large an amount of mind is also concerned in its production: the abilities of first-rate men brought to bear upon it day after day; the incessant activity of reporters at home and of correspondents abroad, whose daily communications pour into this vast magazine of intelligence, to be revised, corrected, and reproduced; advertisers anxious to make known their wants,—their bad writing to be deciphered, their defective grammar corrected, and all the announcements to be classified and properly arranged. To do all this with unceasing regularity requires the well-directed labour of many minds, of many hands, and of many machines, all working in their proper spheres with a well-defined purpose, and guided by one or two presiding minds to a common end.

The preparation of the Catalogue of the Great Exhibition resembled in many respects that of the *Times* newspaper. The typographical efforts were on a scale of similar magnitude; the contributors to it were exceedingly numerous; a large number of persons were engaged in correcting, abridging, and classifying these contributions; many men of eminence in their respective departments assisted with their advice or with written annotations, and the time allowed for the work was exceedingly short. But here the parallel ends. The production of the *Times* newspaper is the result of preconcerted arrangements, founded on the experience of many years: the production of the Exhibition Catalogue was a novel undertaking, in which everything had to be arranged upon possible and probable contingencies; mistakes had to be corrected as they arose; persons whose services were gratuitous had to be stimulated to action; an immense number of individual efforts were to be skilfully guided towards the attainment of a common result within a very limited time. When we consider the novelty and difficulty

of the undertaking, it may well excite surprise that the visitors to the Great Exhibition on the first of May should have found the Official Catalogue ready to their hands.

In order that the reader may understand the merits as well as the difficulties of the subject, we must enter into some detail. Before the articles described were sent to the building in Hyde Park, or while they were on the road thereto, application was made to each contributor for his description of the article which he intended to exhibit. In order to produce as much as possible uniformity in description, printed forms were supplied to the exhibitors, with instructions for filling them up, and suggestions for supplying interesting or important information on certain specified points. There were four varieties of forms, each appropriated to one of the four great Sections of—I. Raw Materials; II. Machinery; III. Manufactures; and, IV. Fine Arts. In their essential features the forms were similar in each Section; but the instructions for filling them up differed, and, for the purpose of facilitating subsequent operations, the forms of the four different sections were printed, the first in black ink, the second in blue, the third in red, and the fourth in yellow. The following is the form used in sending articles of machinery :—

List of Articles of MACHINERY *to be exhibited by*

____________ Exhibitor's Surname. ____________ Christian Name

____________ Country. ____________ Address, stating nearest Post Town.

____________ Capacity in which the Exhibitor appears, whether as *Producer*, *Importer*, *Manufacturer*, *Designer*, *Inventor*, or *Proprietor*.

Number of Articles.	DESCRIPTIONS.

The list of rules supplied with these forms directed that each exhibitor should write his description in a clear hand on paper of the same size as that on which the form was printed (viz. 13 in. by 8 in.), and on one side only, leaving a margin of one inch at the left side of the page. Should the description extend beyond a single page, each separate page was to be marked with the exhibitor's name, and numbered consecutively. The descriptions of the articles were required to set forth as far as possible the following particulars :—

In SECTION I.—RAW MATERIALS and PROCESSES, the descriptions should specify—

a. The commercial name in English, French, and German. *b.* The scientific name. *c.* The place where obtained; the name of the mines, and the time during which they have been worked, should be given with minerals. *d.* The place where exported. *e.* The uses. *f.* The consumption. *g.* The superior excellence of particular specimens. *h.* In the case of processes, such as dyes, or prepared materials, such as mixed metals, it should be stated whether the article is patented or not. The novelty and importance of the prepared product, and the superior skill and ingenuity manifested in the process of preparation, should also be very briefly pointed out. *i.* Where price is an element for consideration, the price at which the importer or producer can sell the article. *j.* Any particular features which the exhibitor desires to be noticed by the Jury.

In SECTION II.—MACHINERY, the descriptions should specify—

a. The uses. *b.* The novelty, if any, in the invention. *c.* Superiority of execution. *d.* Increased efficiency or economy. *e.* The importance of the article in a social or other point of view. *f.* The place where produced. *g.* Whether the article is patented or not. *h.* Where price is an element for consideration, the price at which the producer can sell the article. *i.* Any particular features which the exhibitor desires to be noticed by the Jury.

In SECTION III.—MANUFACTURES :—

a. The uses. *b.* The novelty. *c.* Superiority of execution. *d.* Improved forms or arrangements. *e.* Increased efficiency or economy. *f.* New use of known materials. *g.* Use of new materials. *h.* New combinations of materials. *i.* Importance of the article in a social or other point of view. *j.* The place or places where manufactured. *k.* Whether the manufacture is patented; whether the design is registered. *l.* Where price is an element for consideration, the price at which the importer or manufacturer can sell the article. *m.* Any particular features which the exhibitor desires to be noticed by the Jury.

In SECTION IV.—FINE ARTS, MODELS, SCULPTURE and PLASTIC ART, the descriptions should specify—

a. The name of the artist or designer, if the same should not be the exhibitor. *b.* The uses. *c.* The novelty in design or treatment. *d.* Superiority of execution. *e.* New use of known materials. *f.* Use of new materials. *g.* New combination of materials. *h.* Improvements in processes of production. *i.* The place where the article was made. *j.* If the article is repeated in quantities for trade, the price at which it is sold by the producer should be stated. *k.* Any particular features which the exhibitor desires to be noticed by the Jury.

Exhibitors were required to be brief in their descriptions, and to confine themselves as much as possible to facts. Two copies of each description were required from each exhibitor, which being furnished he was supplied with a receipt for catalogue forms, which became a guarantee for the reception of his goods into the building. A large number of these forms and the accompanying instructions were also supplied to the Local Committees and to all exhibitors on application. The sending out of these forms occupied several men nearly a month, during which time they made up and forwarded upwards of 50,000 printed epistles. Of the two copies of each description sent in, one was retained by the Executive Committee; the other was placed in the hands of the compiler, whose office was opened in the building in Hyde Park on the 21st of January, 1851. The compiler had at first three, and afterwards six assistants. By the end of January the returns began to pour in, and as they came they were sorted into sections, referred to their respective classes, 30 in number, and arranged in alphabetical order. This classification was found to be an exceedingly difficult and tedious undertaking. They were next re-examined, to see that every form was in duplicate: forms that were defective in this respect were supplied in the office. They were examined a third time, and compared with the list of proposed exhibitors, when a number of supernumerary papers which had been sent on speculation were detected and cast out.

It will readily be conceived that the instructions for filling up the forms did impart a certain amount of uniformity to the returns; but many exhibitors neglecting the plain advice of the instructions, committed grave errors. The object of some appeared to be only to praise themselves and advertise their goods; others erred through ignorance; and not a few omitted altogether to forward their returns, or deferred doing so to the very last hour. The first correction of the forms was made in the compiler's office, and consisted in the erasure of obviously superfluous matter. The forms in each class were then numbered and registered, before passing out of the hands of the compiler into those of the printer.

The first packet reached the printer on the 31st of January. On the 31st of March, 6,010 returns from exhibitors in Great Britain and Ireland had been set up, which number had only extended to 6,242 by the 22d of April. The colonial and foreign returns were also being proceeded with, the former being sent to press between the 6th of March and the 21st of April, and the latter between the 3d of February and the 23d of April. Of the foreign returns the first received were those from Tunis, the second were from Lübeck, and the third from Switzerland. It must be understood that all the matter first set up was for the illustrated edition of the Catalogue, and this was kept standing until revised for publication. The proof impressions of these were sent to Mr. Ellis, the scientific editor; and then came the most important part, the real business of revision of the Catalogue. For this purpose the services of a number of scientific men were engaged or volunteered, who brought to bear upon the numerous items of the Catalogue a large amount of peculiar knowledge, or as Mr. Ellis well expresses it, "of knowledge not to be gained by study, but taught by industrial experience, in addition to that higher knowledge, the teaching of natural and experimental philosophy." Mr. Ellis distributed the proofs among these gentlemen, whose duty it was in the first place to revise the exhibitors' own accounts as corrected by the compiler, to prune redundances, to delete self-laudatory terms or critical statements, to correct scientific and technical expressions, to light up obscure sentences, and to correct bad grammar. It was their further duty to add such notes and annotations as would enable the visitor the better to understand the nature, commercial value, or chemical or mechanical principle of the specimen, object, or machine exhibited. No critical remarks, either by way of applause or censure, were admissible.

This part of the work was attended with mechanical difficulties of a novel kind, and almost as great as those which belonged to the collecting the descriptions of so many thousand

exhibitors. The proofs thus distributed, were cut up into separate portions and scattered far and wide over the United Kingdom, and, in many cases, abroad: all of these proofs were thin ribbon-like strips, some of which were not more than 3 inches long, and containing only a few lines. These had all to be collected together again and arranged in their proper places as they were before being cut up and distributed, the annotations, corrections, and notes being carefully retained. A simple plan was contrived for ascertaining the history of each slip of proof; the place of its destination, the name of the annotator, and the date of its transmission and return: these facts could be ascertained at any moment. The annotators, however, with the knowledge had also the precision of scientific men, and returned their proofs with much punctuality. Had it not been so, the plan of the Illustrated Catalogue must have been abandoned, and this splendid permanent record of the Great Exhibition would have lost much of its value.

The slips thus revised and annotated were sent to the printer, who made the necessary corrections and additions, and forwarded the corrected proofs to the editor, who with the assistance of competent persons, re-read them in order to see that the printer had done his work properly. These corrected proofs were then placed in the compiler's hands, who condensed from each item a short description for the Shilling Official Catalogue. The reduction of the whole of the proofs for the British portion of the Exhibition, occupied the compiler up to the 24th of April. The foreign and colonial portion was commenced on the 10th, and finished on the 28th of April, so that the rough proof of the Shilling Catalogue was completed only two days before the opening of the Exhibition. The first perfect impression of the Catalogue was not ready until ten at night of the 30th of April: nevertheless 10,000 catalogues, properly made up and stitched, were delivered at the building on the morning of the 1st of May, together with two copies elegantly bound in morocco, lined with silk, and with gilt edges, for presentation to Her Majesty and Prince Albert.

Such are the extraordinary circumstances under which the first edition of the Official Catalogue was prepared. That it should contain some errors will not excite surprise: it contained descriptions of articles which the describers neglected to send to the Exhibition, and in some cases, articles of great bulk could not be accommodated in the places assigned to them in the Catalogue. These, and errors of smaller note, were, however, corrected in the second edition.

The Official Catalogue consists of 320 pages, or 20 sheets of double foolscap folded into 8. It was sold within the building at one shilling—beyond its precincts at 15*d*. The statistics of the sale of this work belong to our last Section. For the use of our foreign guests, translations of the Catalogue in French and German were also sold at 2*s*. 6*d*. each.

Three mottoes selected by Prince Albert were appended to the Catalogue.

THE EARTH IS THE LORD'S, AND ALL THAT THEREIN IS:
THE COMPASS OF THE WORLD AND THEY THAT DWELL THEREIN.

Ne nostra, ista quæ invenimus, dixeris—
Insita sunt nobis omnium artium semina,
Magisterque ex occulto Deus producit ingenia.

Say not the discoveries we make are our own—
The germs of every art are implanted within us,
And God our instructor, from hidden sources,
Develops the faculties of invention.

Humani generis progressus,
Ex communi omnium labore ortus,
Uniuscujusque industriæ debet esse finis:
Hoc adjuvando,
Dei opt: max: voluntatem exsequimur.

The progress of the human race,
Resulting from the common labour of all men,
Ought to be the final object of the exertion of each individual.
In promoting this end,
We are accomplishing the will of the great and blessed God.

Section IX.—The Opening.

The interest naturally felt by the public in an undertaking in which the character of the British nation was, in so many respects, deeply involved, was constantly stimulated in various ways. The novel character of the building, the rapidity with which it was reared, as well as the marvellous effect of the exterior, could be judged of by a visit to Hyde Park. Those who enjoyed the rare privilege of admission to the interior, such as the reporters to the newspapers, told, from day to day, of the progress of the exhibitors, and even noticed, with some detail, many of the new and striking objects which were being arranged. These circumstances, together with the positive announcement that, notwithstanding the want of preparation in some of the foreign Sections, the building would be opened on the 1st of May by the Queen in person, tended to produce a world-wide excitement, which was, of course, most intensely felt in the metropolis. The admission to the building on the opening-day was by tickets only, and these were supplied by the Society of Arts, at the rate of three guineas for a gentleman, and two guineas for a lady; these tickets admitted the holders to the building, not only on the 1st of May, but at all other times when the public was admitted during the season allotted for keeping open the Exhibition.[1]

Although the admission to the opening ceremony was thus limited, yet the day was, by general consent, regarded as a universal holiday. At an early hour crowds of persons were seen wending their way to the great central point of attraction—the Crystal Palace, as people loved to call it, which, on this May-morn, stood out in its light blue-and-white attire, its brightly polished transept roof flashing in the sun, and the numerous small flags of all nations, with which its long lines of roof were decked, giving it a sparkling appearance;—all this made it look, not like the building of a northern clime, still less of smoky London, but one adapted to uninterrupted sunshine and never-fading foliage. Holders of season tickets were admitted between 9 o'clock and 11.30, A.M. Those who had seen the interior on the previous day, now expressed their astonishment at the order which, in one night, had been created out of an apparent chaos. The exhibitors had accomplished much of their work, but much remained to be done. The English department was tolerably perfect; the foreign was very defective: nevertheless, the foreign exhibitors managed, with much skill, to conceal their deficiencies. The whole area of the building had been rough, and encumbered with the signs of recent labour, and it was the business of the night to clear away all this, and to be ready to receive royal company on the morrow; the rubbish and litter of months of preparation were made to disappear in one night; the centre of the transept and the approach from the north were covered with red cloth; the path down the two sides of each nave covered with matting for the royal procession, and fenced off to prevent the pressure of the crowd. Seats were prepared for the company below, as well as in the galleries. Two elegant tiring-rooms were also rapidly erected for the Queen near the north entrance, and a beautiful silken canopy suspended at a height of thirty feet above the throne. A chair selected from the Indian collection served as a throne, and over it was cast a magnificent scarlet elephant-cloth, richly brocaded. The throne stood upon a raised dais, appropriately covered with the Ladies' Carpet,[2] and before it rose, to a height of twenty-seven feet, the splendid crystal fountain—the appropriate centre-piece of the Palace of Glass.

(1) On the 2d and 3d May, the price of admission was one guinea each person, from the 4th to the 25th May it was 5*s.*; and on and after the 26th May, 1*s.*, except on Fridays, when it was 2*s.* 6*d.*, and on Saturdays, when it was 5*s.*

(2) The *Ladies' Carpet* originated in a suggestion of Mr. W. B. Simpson, that a carpet should be made by ladies, to prove the possibility of equalling the looms of the Continent, and to point out a means of employing educated women who are wanting employment. With these views, a committee was formed, who obtained a design for a carpet 30 feet long by 20 feet wide, and 150 ladies undertook to work it, each lady taking a piece, together with her portion of the pattern which had been prepared by Mr. Simpson. The 150 pieces being completed, were worked and joined together. The design was by Mr. J. W. Papworth, and he very properly excluded from it those scrolls, monster flowers, and solid objects in relief, so common in carpets, which, if they really were the objects which they represent, would make it absolutely impossible to walk over them. His purpose was to produce the effect of a flat surface, the only objects in relief being flowers of the natural size, such as might be supposed to be scattered over the surface of a richly-inlaid floor. The entire number of squares in the canvas upon which the carpet was worked was 17,300,000,—a number which will give some idea of the labour required to produce this remarkable contribution to the Great Exhibition.

Soon after 9 o'clock, the Editor was among the throng of persons who were entering by the eastern door, the south or transept entrance being reserved for carriage visitors, the line of which, at this hour, extended considerably more than a mile towards the east. The seats filled rapidly, and although there were three hours of waiting before the ceremony began, that time was needed to accustom the mind to the sublimity of the scene. We then felt how different was the effect produced by the exterior and the interior of this marvellous building. When viewing the exterior of a Gothic cathedral, the mind can realize the interior; but this may be the result of past experience, which was wanting in the case of the Crystal Palace. The delight occasioned by its exterior arose from the skilful combination of a few simple elements—simplicity of design—vastness of extent—pleasing and harmonious decoration,—all this the mind could comprehend at a glance, and the satisfaction which that glance afforded was confirmed by a more deliberate survey. The interior, on the contrary, furnished as it now was by the contributions of the world, pleased by the vast variety and complication of the combining elements, which required time and study to make out. Now we could only judge of the general effect produced by some of the more striking elements, such as the naves, each, from its great length, skilful decoration, and shaded glass roof, appearing to fade into the blue distance; while bounding the two was the brilliant transept, now made still more brilliant by the rapid succession of visitors, in splendid and varied uniforms and costumes; the galleries were also lined with visitors, whose faces expressed admiration for the present, and hope for the future. In such a building, and at such a time, the mind was filled to overflowing; and an oppression of feeling was produced at the thought of having to study and describe these objects of art, science, and industry.

Long before the hour of noon, a large number of distinguished persons had taken their places around the throne. The members of the Royal Commission were, of course, there, waiting for their royal President; her Majesty's Ministers, the Executive Committee, the Ambassadors of various nations, the Lord Mayor, Sheriffs, and Aldermen of the City of London, the Commissioners of foreign states, formed various interesting groups. Mr. Paxton and Messrs. Fox and Henderson were the observed of all observers. A large number of the aristocracy were also present. The Archbishop of Canterbury, and several of the Bishops; the Lord Chancellor, and other legal dignitaries, wearing the costume which time and old associations have rendered sacred in the eyes of Englishmen; naval and military men, heralds, and beef-eaters, heightened by their costumes the brilliancy of the grouping. The transept galleries were occupied by choristers and numerous vocalists of eminence, as also by a selection of privileged visitors. At least 25,000 persons were present, all waiting, with eager intelligent expectation, for Her whose presence was alone wanting to complete the great gathering of all nations.

The cheers of the crowd and the roar of the cannon, made faint by the distance and the vast size of the building through which they feebly reverberated, announced the approach of the Queen. Suddenly a loud flourish of trumpets from the transept galleries, bespoke Her Majesty's entrance into the building. She was conducted at once to her robing-room, and after a short interval she appeared, accompanied by the Prince and two of the royal children, and attended by her Court, slowly coming forward under the great elm, between stands of choice exotics and tropical plants, fountains and statues, to the throne. Then arose that vast assembly, and gave a cheer such as only a free people can give; ladies waved their handkerchiefs, and all was stir and excitement. Just at that moment, too, the sun appeared from behind a cloud, and poured a flood of light upon the animated scene. Then burst out that wondrous tide of sound, in which thousands of voices prayed God to save our noble Queen; then came another cheer loud and prolonged —another, and yet another! At length impatient enthusiasm consented to be mute, and His Royal Highness Prince Albert having joined the Royal Commissioners, approached the Throne and read a Report of the proceedings of the Commission, in which after very briefly reciting the dates of the Royal Warrant and Charter, the proceedings founded thereupon at home and in the colonies, the selection of a site, the free admission of goods, the appointment of Local Committees, and the collection of subscriptions, His Royal Highness proceeded thus:—

3. Berlin Wool, Chair Covers and Fancy Articles for the Drawing Room. 4. Embroidery by Machinery.

E. Fringes, &c.

1. Fringes, Tassels, Gymps, &c., suitable as Trimmings for Upholstery. 2. Ditto, for Dresses and other fine Work.

F. Fancy and Industrial Works.

1. Berlin Wool Work. 2. Needle-work. 3. Miscellaneous Industrial Works.

Localities of Exhibition.

E. 1. London; 2. Derby and London.

Class XX. *Articles of Clothing for Immediate, Personal, or Domestic Use.*

A. Hats, Caps, and Bonnets.

1. Hats, made of Silk, Beaver, or other materials, for Men.
2. Caps, for Men.
3. Bonnets of Straw, Silk or other material.
   a. British Chip Bonnet made from the Poplar. *b.* Willow Bonnet. *c.* Brazilian Grass Hats. *d.* Tuscan and Leghorn Plaiting and Bonnets. *e.* Straw Plait Bonnets. *f.* Straw Trimmings and Bonnets. *g.* Horse Hair Trimmings and Bonnets. *h.* Silk and other Bonnets made by Milliners.

B. Hosiery.

1. Cotton. 2. Woollen. 3. Linen. 4. Silk.

C. Gloves.

1. Made of Leather or Skins. 2. Made of any other materials.

D. Boots, Shoes, and Lasts.

1. Made of Leather. 2. Made of other materials.

E. Under Clothing.

1. For Ladies. 2. For Gentlemen.

F. Upper Clothing.

1. For Ladies, including all kinds of Millinery. 2. For Gentlemen, including all kinds of Tailor's-work.

Localities of Exhibition.

A. 1. London, Newcastle-under-Lyne, Manchester, Stockport, Oldham, Bristol; 2. London, Bristol, and other large towns; 3. London, Tring, St. Albans, Halstead, Heddingham, &c. Chesham. Dublin, Dunstable, London, &c. B. Leicester, Nottingham, Perth, Balbriggan, Tewkesbury, Loughborough, Wells, Hawick, Dumfries, Aberdeen, Bala, Kendal.

Localities of Exhibition.

C. Worcester, Dundee, Yeovil, Woodstock, Limerick, &c. D. Northampton, Stafford, London, Norwich, &c. E. Nottingham, Leicester, Derby, Godalming, Wells, Somerset, Hawick, Dumfries, &c. F. All large towns.

Class XXI. *Cutlery and Edge-tools.*

A. Cutlery, such as Knives and Forks, Pen and Pocket Knives, Razors, Scissors, and Shears.

1. Knives and Forks—Table, Dessert, Carving. Dessert or Fruit, with plated and silver blades. Cake and Melon Carvers, with ditto. Fish Knives and Forks, with ditto. 2. Spring Knives—Pen and Pocket Knives of every description. Hunting and Sportsmen's Knives. 3. Knives of all other descriptions—Paper Knives of all kinds. Desk or Office Knives. Palette Knives. Knives for Hunting and Self-defence, as Couteaux-de-Chasse, Bowie Knives, &c. Knives for Kitchen and Domestic Purposes, as Cook's, Oyster, Onion, Bread and Butter, and Cheese Knives. Knives used in various Trades, as Butchers, Shoemakers, Glaziers, Gardeners, &c. 4. Scissors and Shears—Ladies' Work and Cutting-out Scissors of every description. Nail, Button-hole, Barbers', and Trimming Scissors. Shears used in various Trades, as Tailors, Brush-makers, &c. Garden and Sheep Shears. 5. Razors of all kinds. 6. Miscellaneous—Corkscrews, Button-hooks, Boot-hooks, Nail-nippers, Nail-files, Tweezers, &c.

B. Files and other small Edge Tools, not included in Manufacturing Tools in Section VI.

1. Files and Edge-tools used by Engineers, Smiths, or other Metal Workers;—2. for purposes of Building, by Masons, Bricklayers, and Plasterers;—3. for fine Metal and other work, as for Clock and Watchmakers, Jewellers, Lapidaries, Engravers, and Modellers;—4. for Wood-work, as for Carpenters, Joiners, Cabinet-makers, Coopers, &c.;—5. for Leather or Skins, as for Saddlers, Curriers, Shoemakers, and Bookbinders;—6. Drawing, Artist's, and Engraving Instruments. 7. Files and Edge-tools for other purposes than those specified.

Localities of Exhibition.

A. Sheffield, London, Birmingham.

Localities of Exhibition.

B. Sheffield, Warrington.

Class XXII. *Iron and General Hardware.*

A. Brass Manufacture.

1. Cabinet and general Brass Foundry, consisting of Hinges, Fastenings, Escutcheons, Bell-pulls, Brassfoundry used in Ships, Knockers, Door-springs, Castors, &c. 2. Plumbers' Brass Foundry Cocks, Valves, Pumps, Water-closets, &c. 3. Stamped Brass Foundry, Cornices, Curtain-bands, Finger-plates, &c. 4. Gas-fittings, Brackets, Chandeliers, Pillars, Gas-burners, and Consumers' Meters, &c. 5. Tubing, plain and ornamental. 6. Metallic Bedsteads, brass and iron. 7. Chandeliers, Lamps, and Candelabra, for Oil, Candles, or Camphine, and Lamp Chains. 8. Railway and Carriage Brassfoundry, and Signal Lamps and Lanterns. 9. Bronze Figures, Busts, and Chimney Ornaments. 10. Bells, House, Church, Ship, Table, &c., and Alarums. 11. Candlesticks, Table and Bedroom. 12. Monumental Brasses and Ecclesiastical Brass-work. 13. Copper and Steel Plates, for Engravers. 14. Miscellaneous.

B. Copper, Zinc, Tin, Pewter, and General Braziery.

1. Kettles, Coal Scuttles, Coppers, Saucepans, Steamers, Plate-warmers, &c. 2. Bronzed Tea and Coffee Urns, Kettles, &c. 3. Tubing—

Localities of Exhibition.

A. Birmingham, London, Dublin.

Localities of Exhibition.

B. Birmingham, London, Sheffield.

Copper, Tin, Lead, &c. 4. Pewter, German Silver, and Britannia-metal Tea-pots, Basins, Dishes, Spoons, Ladles, Inkstands, &c. 5. Coffin Furniture—Plates, Escutcheons, &c. 6. Zinc Articles generally.

C. Iron Manufacture. (See also I. and V.)

1. Stoves, Grates, Fenders and Fire Irons, Kitchen Ranges, Cooking Apparatus, Smoke-jacks. 2. Warming Apparatus, for Halls and Rooms, Ships, &c., either by Water, Coal, Coke, Wood, Charcoal, or Gas. 3. Shower, Vapour, Air, and Warm-water Baths. 4. Ventilators—Metallic and others. 5. Pipes and Gutters, &c. 6. Locks and Hinges. 7. General Ironmongery. 8. Ice Machines. 9. Knife-cleaning Machines. 10. Letter-copying Machines and Presses. 11. Saddlers' Ironmongery. 12. Hollow Ware, cast and wrought, tinned and enamelled. 13. Spades, Shovels, Pickaxes, Hoes, Rakes, Garden-rollers, &c. (See also J. IX.) 14. Nails, cut, cast, and wrought, in Iron, Copper, and other Metals. 15. Screws and Railway Bolts, &c. 16. Iron Safes, Cash-boxes, fire-proof and otherwise. 17. Horse-shoes. 18. Gates, Railings, Hurdles, and Stable Fittings. 19. Mangles, Washing Machines, &c.

D. Steel Manufacture.

1. Tools and heavy Steel Toys, Hammers, Vices, &c. 2. Steel Ornaments, and light fancy Steel Toys, Brooches, Buckles, &c. 3. Steel Pens and Metallic Pens. 4. Needles, Fish-hooks, and Fishing Tackle.

E. Buttons, &c.

1. Buttons—Metallic, Florentine, Pearl, Bone, &c. 2. Metal Boxes, Watch Boxes, &c.

F. Wire Work, &c.

1. Wire Gauze, and Window Blinds, Fencing, Pheasantry, Birdcages, &c. 2. Wire—Iron, Brass, Steel, and Copper. 3. Pins—white and black. 4. Hooks and Eyes. 5. Metallic Wire Baskets. 6. Wire Rope.

Localities of Exhibition.

C Sheffield, Birmingham, Wolverhampton, Walsall, West Bromwich, London.

Localities of Exhibition.

D. Birmingham, Redditch. E. Birmingham, F. Birmingham.

Class XXIII. *Working in Precious Metals and in their imitations; Jewellery, and all Articles of Virtu and Luxury not included in the other Classes.*

A. Communion Services.

As Altar-dishes, Flagons, Chalices, Patens, Plates, &c.

B. Articles of Gold and Silver Plate, for Decorative Purposes and Presentation Pieces.

1. Racing Prizes, Testimonials, allegorical, historical, and emblematic Groups and Compositions, Shields, Centre Pieces, Vases, Tazzas, Ewers, Salvers, Candelabra, &c. 2. The same Articles made in hammered or repoussé metal.

C. Smaller Articles for more general Domestic Use.

1. For the Dinner Table; as Smaller Candelabra with branches, Candlesticks, Centre Pieces, Soup and Sauce Tureens, Covered Dishes, Smaller Mounted Dishes, Flat Dishes, Flower-stands and Epergnes, Dessert Services, Table and Dessert Knives, Spoons and Forks, Salvers, Bread and Cake Baskets, Claret Jugs, Wine Coolers, Cruet Frames, Mustard Pots, Salts, &c. 2. Breakfast and Tea-table Service; as Tea and Coffee Urns and Kettles, Tea and Coffee Pots and Stands, Sugar Basins, Milk and Cream Jugs, Ewers and Basins, Toast Racks, &c. 3. Dressing and Library Table and Travelling Utensils; as Inkstands and Writing Appendages, Dressing Cases and Instruments, &c. 4. Miscellaneous; as Watch and Clock Cases, Toys, Pencil Cases, Seals and Keys, Filagree Baskets and Ornaments.

D. Electro-plated Goods of all descriptions, comprehending all that can be executed in Silver and other Metals.

E. Sheffield and other plated Goods.

1. Centre and Side covered Dishes and Warmers, Soup Tureens, Cruet Frames, Liqueur Frames, Pickle ditto, Candlesticks and Branches, Candelabra, Bread and Cake Baskets, Snuffers and Trays, Tea and Coffee Services, Tea Trays, Hand Waiters, Claret Jugs, Decanter Stands, Sugar Stands, Flower Stands, Nut Crackers, Grape Scissors, Mustard Pots, &c. &c.

F. Gilt and Ormolu Work.

1. Gilt by the Electro process. 2. Gilt by amalgamation, or "Water Gilding." 3. Imitation Jewellery and Toys.

G. Jewellery.

1. Works exhibiting the Precious Stones and Pearls, as Diamonds, Rubies, Sapphires, Emeralds, Opals, Turquois; and the manner of setting them in Crowns, Coronets, Stars, Orders, Tiaras, Head Ornaments, Bouquets, Necklaces, Bracelets, and Armlets, Presentation Snuff Boxes, Brooches, Ear Pendants, Medallions, Studs, and Buttons. 2. Ornaments similar to those of the former class, in which are exhibited the setting of the Inferior Stones, as Amethysts, Topazes, Carbuncles, Aquamarines, Jacynths, Crysophrases, Carnelians, Onyxes, whether plain or set, Cameos or Intaglios, Engraved Shells, &c. &c. 3. Ornaments made of Gold, whether plain or enamelled; as Bracelets, Brooches, Necklaces, Ear-rings, Pins, Waist-Buckles, Chains, Buckles, Studs, Chatelaines, &c. &c. &c 4. Jewellery by imitations of Precious and other Stones. 5. Ornaments worked in Ivory, Jet, Horn, Hair, and other materials of which the Precious Stones or Metals do not form the principal feature.

H. Ornaments and Toys worked in Iron, Steel, and other Metals, which are neither Precious Metals nor Imitations of them, as Chatelaines of Steel, Chains of Steel, Sword-hilts, Cut Steel Shoe and Knee Buckles, Berlin Iron Ornaments, Chains, Necklaces, Bracelets, &c.

Localities of Exhibition.

B. London, &c. C. London, Birmingham, Sheffield, Edinburgh, &c. D. Birmingham, London, Sheffield. E. Sheffield, Birmingham, London, &c.

Localities of Exhibition.

F. London, Birmingham, &c. G. London, Birmingham, Edinburgh, Dublin, &c. H. London, Birmingham, Sheffield, &c.

I. Enamelling and Damascene Work.

1. Enamelling of subjects on Gold and Precious Metals. (Except when shown in the Section of Fine Arts.) 2. Damascene Work, or insertion of one Metal in another, not included in the above-named Classes, as forming a minor ingredient in some more important species of Manufactures.

J. Articles of Use or Curiosity not included in the previous enumeration.

Class XXIV. *Glass.*

A. Window Glass, including Sheet Glass, Crown Glass, and Coloured Sheet Glass.

1. Crown. 2. Sheet. 3. Blown Plate Glass, silvered and unsilvered. 4. Coloured Sheet, Pot Metal, or flashed. 5. Glass Ventilators. 6. Glass Shades, round, oval and square.

B. Painted and other kinds of Ornamented Window Glass.

1. Enamelled, Embossed, Etched, painted white, or coloured Window Glass. 2. Painted and Leaded Windows.

C. Cast Plate Glass.

1. Rough Plate. 2. Ground and Polished, silvered and unsilvered. 3. Pressed Plate. 4. Rolled Plate, white and coloured.

D. Bottle-glass.

1. Ordinary Bottle-glass, including Moulded Bottles. 2. Medicinal Bottle-glass, including Phials, &c., blown and moulded, of all kinds and shapes. 3. White Bottle-glass, Blown, Pressed, and Moulded Bottles. 4. Water-pipes and Tubing.

Localities of Exhibition.

A. Birmingham, Bristol, St. Helens, Shields, Sunderland, Newcastle, London. B. Edinburgh, Glasgow, Sunderland, Newcastle, St. Helens, Shrewsbury, York, Warwick, London, Birmingham. C. London, Birmingham, St. Helens, Shields, Sutton, Ravenhead, Sunderland. D. Bristol, Sunderland, Shields, Newcastle, Castle Ford, St. Helens, Glasgow, Greenock, Dudley, Bristol.

E. Glass for Chemical and Philosophical Apparatus.

1. Glass for Matras, Retorts, and other kinds of Chemical and Philosophical Apparatus. 2. Water-pipes and Tubing.

F. Flint-glass or Crystal, with or without Lead, white, coloured, and ornamented, for Table Vases, &c.

1. Blown. 2. Moulded and Pressed. 3. Cut and Engraved. 4. Reticulated and spun with a variety of colours, incrusted, flashed, enamelled of all colours, opalescent, imitation of Alabaster, gilt, platinised, silvered, &c. 5. Glass Mosaic, Millefiori, Aventurine, and Venetian Glass Weights, &c. 6. Beads, imitation Pearls, &c. 7. Chandeliers, Candlesticks, and all Glass Apparatus for Lamps, Candlesticks, Gerandoles, Wall Brackets, with or without drops, &c.

G. Optical Glass, Flint and Crown.

1. Rough Discs of Flint and Crown, to make Lenses for Telescopes, Microscopes, Daguerreotype and Calotype Apparatus, &c. 2. Flint and Crown, blown or cast in plates for the Optician. 3. Thin Glass for Microscope. 4. Refractive Apparatus, Prismatic Lenses for Light-houses (see also Class J).

Localities of Exhibition.

E. Stourbridge, Birmingham, London, Newcastle. F. London, Stourbridge, Birmingham, Newcastle, Dudley, Edinburgh, Glasgow, Greenock. G. London, Birmingham, Newcastle, Shields.

Class XXV. *Ceramic Manufactures.—Porcelain, Earthenware. &c.*

A. Porcelain, Hard.

1. Chinese. 2. Japanese. 3. Continental, as Berlin, Meissen, &c.

B. Statuary Porcelain.

1. Statuary. 2. Parian. 3. Carrara.

C. Tender Porcelain.

1. English Porcelain, soft or tender. 2. French, with Siliceous body.

D. Stoneware, Glazed and Unglazed.

1. Ironstone, or Stone China, glazed. 2. White Stone body; 3. Coloured body, Jasper; 4. Egyptian black, 5. Red, 6. Cane, 7. Drab (all unglazed). 8. Brownware, with salt glaze. (The Lambeth, Chesterfield, and Beauvais manufactures are included in this class.) 9. Chemical utensils. (These are made both in Stoneware and Hard Porcelain.)

E. Earthenware.

1. White body for Printing, Painting, or Enamelling in different Colours. 2. Common Cream colour. 3. Green glazed ware. 4. Rockingham, 5. Delph, 6. Majolica, 7. Mocha and Dipt wares. 8. Common lead glazed ditto, for utensils. 9. Coloured body, Turquoise, 10. Drab, 11. Olive, 12. Buff, 13. Cottage brown.

Localities of Exhibition.

A. Stoke-upon-Trent. B. Staffordshire Potteries, Coalport. C. Staffordshire Potteries, Coalport, Worcester. D. 1—7. Staffordshire Potteries; 8. Lambeth and Vauxhall. E. Staffordshire Potteries, Newcastle-upon-Tyne, Glasgow, Sunderland, Bristol,

F. Terra Cotta.

1. Vases and Garden Pots. 2. Ornaments for Architecture. 3. Encaustic or Inlaid Tiles. 4. Tesseræ of various colours, compressed from powdered clay. 5. Superior Plain Tiles for Pavements; 6. Bricks; 7. Roofing Tiles (all from powdered clay). 8. Chimney Pipes. 9. Common Bricks. 10. Common Roofing Tiles, &c.

G. Ornamented or Decorated.

1. Ornamented on *Bisque* — Painted by hand. Printed and Transferred in various colours. 2. Ornamented *on the glaze* — Painted by hand. Printed by the press. Printed by hand. Gold, Silver, and Steel Lustre. Enamelling in various colours. Gilding.

H. Productions for Architectural Purposes.

Localities of Exhibition.

Swansea, Stockton-upon-Tees. F. 1—3. Staffordshire Potteries, and other places in the United Kingdom; 4. Stoke-upon-Trent. G. All the various localities mentioned above.

Class XXVI. *Decoration Furniture and Upholstery, including Paper Hangings, Papier Maché, and Japanned Goods.*

A. Decoration generally, including Ecclesiastical Decoration.

1. Ecclesiastical Decoration generally. 2. Ornamental coloured Decoration, as executed by hand. 3. Imitations of Woods, Marbles, &c., executed by hand. 4. Relievo Decoration, mechanically produced.

Localities of Exhibition.

A. London, Edinburgh, Glasgow, Birmingham, &c.

B. Furniture and Upholstery.

1. Cabinet Work, plain. 2. Cabinet Work, carved or ornamental. 3. Marqueterie, in-laid Work, in Woods, &c. 4. Buhl or Metallic in-laid Work. 5. Chairs, Sofas, and Beds, and general Upholstery.

C. Paper Hangings.

1. Damask patterns. 2. Flower patterns. 3. Flock and Metal Papers. 4. Decorative Paper-hangings by Block-work; 5. by any other process. 6. Machine-printed Paper-hangings.

D. Papier Maché, Japanned Goods, Pearl, and Tortoiseshell Work.

1. Papier Maché, japanned, inlaid, and decorated. 2. Papier Maché (not japanned), produced in ornamental forms for decoration. 3. Japanned Goods in Iron, &c. 4. Pearl and Tortoiseshell Work.

Localities of Exhibition.

B. London, and most provincial towns. C. London, and Manchester.

D. London, Birmingham, Wolverhampton, Bilston

Class XXVII. *Manufactures in Mineral Substances used for Building or Decorations, as in Marble, Slate, Porphyries, Cements, Artificial Stones, &c.*

A. Manufactures in Common Stones.

1. For building, and constructions not strictly decorative. 2. For decorative purposes.

B. Manufactures in Slate.

1. For Construction. 2. For Decoration.

C Manufactures in Cement and Artificial Stone.

D. Manufactures in Marbles, Granites, Porphyries, Alabaster, Spar, &c., for useful or ornamental Purposes.

1. For construction and external decoration. 2. For internal decoration (not furniture), as Chimney-pieces, &c. 3. For articles of furniture, as Tables, &c. 4. For purposes of mere ornament.

E. Inlaid Work in Stone, Marble, and other Mineral Substances.

F. Ornamental Work in Plaster, Composition, Scagliola, Imitation Marble, &c.

G. Combinations of Iron and other Metals with Glass and other Substances for various useful purposes.

1. For architectural purposes. 2. For Miscellaneous purposes.

Localities of Exhibition.

B. Wales, Devon, London. C. London, Staffordshire, Bath, Southampton, Ipswich, Dorsetshire, Ireland. D. Derbyshire, Devonshire, Cornwall, Aberdeen, &c.

F. London, Derbyshire. G. London, Birmingham, &c.

Class XXVIII. *Manufactures from Animal and Vegetable Substances, not being Woven, Felted, or included in other Sections.*

A. Manufactures from Caoutchouc.

1. Impermeable articles — Boots. Holdsworth's Life Preservers. Captain Smith's ditto. Hydrostatic and Air Beds. Water and Air Cushions. Gas Bags. Printers' Blankets. Cloaks, Capes, Coats, Paletots, &c. Boots and Shoes. Over Shoes, or Goloshes. Fishing and Deck Boots. Ship Sheets. Bellows. Air-pump Valves for Steam Engines. Sponge Baths and Bags. Prepared Water and Air-proof Textures of every description. 2. Elastic Articles—Railway and other Carriage Springs. Railway Buffers. Valve Canvas. Knee Caps. Surgical Bottles. Pump-buckets and Valves. Bands and Rings for Letters and Packages. Writing Tablets. Trouser Straps. Gussets for Boots. Vest Backs. Washers for Flange and Socket Joints. Driving Bands for Machinery. Railway Felt. Wheel Tires. E. Smith's Torsion Springs for Window-blinds, and Shades. Door Springs. Dr. Bell's Sewer and Sink Valves. Hodges's Projectile and Lifting Straps. Air-pump Valves. Elastic Webbing. Cricket Gloves and Balls. Stoppers for Decanters, Bottles, Jars, and other vessels. 3. Articles in Caoutchouc—Moulded, Embossed, Coloured, and Printed. Bas Reliefs. Bags. Maps, printed on Caoutchouc. Sheets in Colour. Embossed and Printed Ornaments. Garters, Bracelets, &c., Embossed, Coloured or Printed. Bottles, Embossed and in Colours. Embossed Sheets for Seats and other purposes. Vulcanized Articles combined with Metal — such as Decanter Stoppers, Inkstands, Cocks and Taps for Fluids, Hinges, Locks, and Bolts, Wheel Tires, Plugs for Cisterns, Linings of Vessels, &c.

B. Manufactures from Gutta Percha.

1. For Waterproofing Purposes. 2. For Agricultural Uses, as Tubing for Manure, &c. 3. For Maritime Purposes, as Speaking Trumpets, Life Buoys, Life Boats, Cords, Tiller Ropes, &c. 4. Decorative Uses, as Ornamental Mouldings, Brackets, Medallions, Picture Frames, &c. 5. Surgical, Electrical, and Chemical Uses, as Dissolved Gutta Percha for wounds, Stethoscopes, Splints, Ear Trumpets, &c., Carboys, Funnels, Acid Vessels, &c., Covering of Telegraph Wire, Insulating Stools, &c. 6. Domestic and Miscellaneous Uses, as Soles for Shoes, Linings of Cisterns, Conveyance of Water and Gas, Hearing Apparatus, &c.

C. Manufactures from Ivory, Tortoiseshell, Shells, Bone, Horn, Bristles, and Vegetable Ivory.

D. General Manufactures from Wood (not being Furniture).

1. Turnery. 2. Carving, &c. 3. Coopers' Work of all kinds. 4. Basket and Wicker-work. 5. Miscellaneous Wood-work.

E. Manufactures from Straw, Grass, and other similar Materials.

F. Miscellaneous Manufactures from Animal and Vegetable Substances.

Class XXIX. *Miscellaneous Manufactures, and Small Wares.*

A. Perfumery and Soap.

B. Articles for Personal Use, as Writing Desks, Dressing Cases, Workboxes, when not exhibited in connexion with Precious Metals (XXIII.), and Travelling Gear generally.

C. Artificial Flowers.

D. Candles, and other means of giving Light.

E. Confectionary of all kinds.

F. Beads and Toys, when not of Hardware, Fans, &c.

G. Umbrellas, Parasols, Walking-sticks, &c.

H. Fishing tackle of all kinds, Archery.

I. Games of all kinds.

J. Other Miscellaneous Manufactures.

FINE ARTS.

(So far as they come within the limitations of the Exhibition.)

Class XXX. *Sculpture, Models, and Plastic Art.*

A. Sculpture as a Fine Art.

1. In Metals simple, as Gold, Silver, Copper, Iron, Zinc, Lead, &c. 2. In Metals compound, as Bronze, Electrum, &c. 3. In Minerals simple, as Marble, Stone, Gems, Clay, &c. 4. In elaborate Mineral Materials, as Glass, Porcelain, &c. 5. In Woods and other Vegetable Substances. 6. In Animal Substances, as Ivory, Bone, Shells, Shell Cameos.

B. Works in Die-sinking, Intaglios.

1. Coins, Medals, and Models of a Medallic character in any material. 2. Impressions struck from Dies for ornamental purposes. 3. Gems, either in Cameo or in Intaglio, Shell Cameos. 4. Seals, &c.

C. Architectural Decorations.

1. Integral, in Relief, Colour, &c. 2. Adventitious, as Stained Glass, Tapestry, &c.

D. Mosaics and Inlaid Works.

1. In Stone. 2. In Tiles. 3. In Vitrified Materials 4. In Wood. 5. In Metal.

E. Enamels.

1. On Metals. 2. On China. 3. On Glass.

F. Materials and Processes applicable to the Fine Arts generally, including Fine Art Printing, Printing in Colour, &c. &c.

1. Encaustic Painting and Fresco. 2. Ornamental Printing, Chromo-typography, Gold-Illuminated Typography, Typography combined or uncombined with Embossing. 3. Lithography Black, Chromo-lithography, Gold-Illuminated Lithography, Lithography combined or uncombined with Embossing. 4. Zincography or other modes of Printing.

G. Models.

1. In Architecture. 2. In Topography. 3. In Anatomy.

Section VIII.—The Catalogue.

There is perhaps no literary undertaking more wonderful than the production of a daily newspaper such as the *Times.* This paper, with its Supplement, consists of 72 columns, or 17,500 lines, made up of upwards of a million pieces of type. To produce 30,000 or 40,000 copies of such a work every day is a mechanical marvel, which becomes indeed impressive when we consider how large an amount of mind is also concerned in its production: the abilities of first-rate men brought to bear upon it day after day; the incessant activity of reporters at home and of correspondents abroad, whose daily communications pour into this vast magazine of intelligence, to be revised, corrected, and reproduced; advertisers anxious to make known their wants,—their bad writing to be deciphered, their defective grammar corrected, and all the announcements to be classified and properly arranged. To do all this with unceasing regularity requires the well-directed labour of many minds, of many hands, and of many machines, all working in their proper spheres with a well-defined purpose, and guided by one or two presiding minds to a common end.

The preparation of the Catalogue of the Great Exhibition resembled in many respects that of the *Times* newspaper. The typographical efforts were on a scale of similar magnitude; the contributors to it were exceedingly numerous; a large number of persons were engaged in correcting, abridging, and classifying these contributions; many men of eminence in their respective departments assisted with their advice or with written annotations, and the time allowed for the work was exceedingly short. But here the parallel ends. The production of the *Times* newspaper is the result of preconcerted arrangements, founded on the experience of many years: the production of the Exhibition Catalogue was a novel undertaking, in which everything had to be arranged upon possible and probable contingencies; mistakes had to be corrected as they arose; persons whose services were gratuitous had to be stimulated to action; an immense number of individual efforts were to be skilfully guided towards the attainment of a common result within a very limited time. When we consider the novelty and difficulty

of the undertaking, it may well excite surprise that the visitors to the Great Exhibition on the first of May should have found the Official Catalogue ready to their hands.

In order that the reader may understand the merits as well as the difficulties of the subject, we must enter into some detail. Before the articles described were sent to the building in Hyde Park, or while they were on the road thereto, application was made to each contributor for his description of the article which he intended to exhibit. In order to produce as much as possible uniformity in description, printed forms were supplied to the exhibitors, with instructions for filling them up, and suggestions for supplying interesting or important information on certain specified points. There were four varieties of forms, each appropriated to one of the four great Sections of—I. Raw Materials; II. Machinery; III. Manufactures; and, IV. Fine Arts. In their essential features the forms were similar in each Section; but the instructions for filling them up differed, and, for the purpose of facilitating subsequent operations, the forms of the four different sections were printed, the first in black ink, the second in blue, the third in red, and the fourth in yellow. The following is the form used in sending articles of machinery :—

List of Articles of MACHINERY *to be exhibited by*

―――――――――― Exhibitor's Surname. ―――――――――― Christian Name.
―――――――――― Country. ―――――――――― Address, stating nearest Post Town.
―――――――――― Capacity in which the Exhibitor appears, whether as *Producer, Importer, Manufacturer, Designer, Inventor,* or *Proprietor.*

Number of Articles.	DESCRIPTIONS.

The list of rules supplied with these forms directed that each exhibitor should write his description in a clear hand on paper of the same size as that on which the form was printed (viz. 13 in. by 8 in.), and on one side only, leaving a margin of one inch at the left side of the page. Should the description extend beyond a single page, each separate page was to be marked with the exhibitor's name, and numbered consecutively. The descriptions of the articles were required to set forth as far as possible the following particulars :—

In SECTION I.—RAW MATERIALS and PROCESSES, the descriptions should specify—

a. The commercial name in English, French, and German. *b.* The scientific name. *c.* The place where obtained; the name of the mines, and the time during which they have been worked, should be given with minerals. *d.* The place where exported. *e.* The uses. *f.* The consumption. *g.* The superior excellence of particular specimens. *h.* In the case of processes, such as dyes, or prepared materials, such as mixed metals, it should be stated whether the article is patented or not. The novelty and importance of the prepared product, and the superior skill and ingenuity manifested in the process of preparation, should also be very briefly pointed out. *i.* Where price is an element for consideration, the price at which the importer or producer can sell the article. *j.* Any particular features which the exhibitor desires to be noticed by the Jury.

In SECTION II.—MACHINERY, the descriptions should specify—

a. The uses. *b.* The novelty, if any, in the invention. *c.* Superiority of execution. *d.* Increased efficiency or economy. *e.* The importance of the article in a social or other point of view. *f.* The place where produced. *g.* Whether the article is patented or not. *h.* Where price is an element for consideration, the price at which the producer can sell the article. *i.* Any particular features which the exhibitor desires to be noticed by the Jury.

In SECTION III.—MANUFACTURES :—

a. The uses. *b.* The novelty. *c.* Superiority of execution. *d.* Improved forms or arrangements. *e.* Increased efficiency or economy. *f.* New use of known materials. *g.* Use of new materials. *h.* New combinations of materials. *i.* Importance of the article in a social or other point of view. *j.* The place or places where manufactured. *k.* Whether the manufacture is patented; whether the design is registered. *l.* Where price is an element for consideration, the price at which the importer or manufacturer can sell the article. *m.* Any particular features which the exhibitor desires to be noticed by the Jury.

In SECTION IV.—FINE ARTS, MODELS, SCULPTURE and PLASTIC ART, the descriptions should specify—

a. The name of the artist or designer, if the same should not be the exhibitor. *b.* The uses. *c.* The novelty in design or treatment. *d.* Superiority of execution. *e.* New use of known materials. *f.* Use of new materials. *g.* New combination of materials. *h.* Improvements in processes of production. *i.* The place where the article was made. *j.* If the article is repeated in quantities for trade, the price at which it is sold by the producer should be stated. *k.* Any particular features which the exhibitor desires to be noticed by the Jury.

Exhibitors were required to be brief in their descriptions, and to confine themselves as much as possible to facts. Two copies of each description were required from each exhibitor, which being furnished he was supplied with a receipt for catalogue forms, which became a guarantee for the reception of his goods into the building. A large number of these forms and the accompanying instructions were also supplied to the Local Committees and to all exhibitors on application. The sending out of these forms occupied several men nearly a month, during which time they made up and forwarded upwards of 50,000 printed epistles. Of the two copies of each description sent in, one was retained by the Executive Committee; the other was placed in the hands of the compiler, whose office was opened in the building in Hyde Park on the 21st of January, 1851. The compiler had at first three, and afterwards six assistants. By the end of January the returns began to pour in, and as they came they were sorted into sections, referred to their respective classes, 30 in number, and arranged in alphabetical order. This classification was found to be an exceedingly difficult and tedious undertaking. They were next re-examined, to see that every form was in duplicate: forms that were defective in this respect were supplied in the office. They were examined a third time, and compared with the list of proposed exhibitors, when a number of supernumerary papers which had been sent on speculation were detected and cast out.

It will readily be conceived that the instructions for filling up the forms did impart a certain amount of uniformity to the returns; but many exhibitors neglecting the plain advice of the instructions, committed grave errors. The object of some appeared to be only to praise themselves and advertise their goods; others erred through ignorance; and not a few omitted altogether to forward their returns, or deferred doing so to the very last hour. The first correction of the forms was made in the compiler's office, and consisted in the erasure of obviously superfluous matter. The forms in each class were then numbered and registered, before passing out of the hands of the compiler into those of the printer.

The first packet reached the printer on the 31st of January. On the 31st of March, 6,010 returns from exhibitors in Great Britain and Ireland had been set up, which number had only extended to 6,242 by the 22d of April. The colonial and foreign returns were also being proceeded with, the former being sent to press between the 6th of March and the 21st of April, and the latter between the 3d of February and the 23d of April. Of the foreign returns the first received were those from Tunis, the second were from Lübeck, and the third from Switzerland. It must be understood that all the matter first set up was for the illustrated edition of the Catalogue, and this was kept standing until revised for publication. The proof impressions of these were sent to Mr. Ellis, the scientific editor; and then came the most important part, the real business of revision of the Catalogue. For this purpose the services of a number of scientific men were engaged or volunteered, who brought to bear upon the numerous items of the Catalogue a large amount of peculiar knowledge, or as Mr. Ellis well expresses it, "of knowledge not to be gained by study, but taught by industrial experience, in addition to that higher knowledge, the teaching of natural and experimental philosophy." Mr. Ellis distributed the proofs among these gentlemen, whose duty it was in the first place to revise the exhibitors' own accounts as corrected by the compiler, to prune redundances, to delete self-laudatory terms or critical statements, to correct scientific and technical expressions, to light up obscure sentences, and to correct bad grammar. It was their further duty to add such notes and annotations as would enable the visitor the better to understand the nature, commercial value, or chemical or mechanical principle of the specimen, object, or machine exhibited. No critical remarks, either by way of applause or censure, were admissible.

This part of the work was attended with mechanical difficulties of a novel kind, and almost as great as those which belonged to the collecting the descriptions of so many thousand

exhibitors. The proofs thus distributed, were cut up into separate portions and scattered far and wide over the United Kingdom, and, in many cases, abroad: all of these proofs were thin ribbon-like strips, some of which were not more than 3 inches long, and containing only a few lines. These had all to be collected together again and arranged in their proper places as they were before being cut up and distributed, the annotations, corrections, and notes being carefully retained. A simple plan was contrived for ascertaining the history of each slip of proof; the place of its destination, the name of the annotator, and the date of its transmission and return: these facts could be ascertained at any moment. The annotators, however, with the knowledge had also the precision of scientific men, and returned their proofs with much punctuality. Had it not been so, the plan of the Illustrated Catalogue must have been abandoned, and this splendid permanent record of the Great Exhibition would have lost much of its value.

The slips thus revised and annotated were sent to the printer, who made the necessary corrections and additions, and forwarded the corrected proofs to the editor, who with the assistance of competent persons, re-read them in order to see that the printer had done his work properly. These corrected proofs were then placed in the compiler's hands, who condensed from each item a short description for the Shilling Official Catalogue. The reduction of the whole of the proofs for the British portion of the Exhibition, occupied the compiler up to the 24th of April. The foreign and colonial portion was commenced on the 10th, and finished on the 28th of April, so that the rough proof of the Shilling Catalogue was completed only two days before the opening of the Exhibition. The first perfect impression of the Catalogue was not ready until ten at night of the 30th of April: nevertheless 10,000 catalogues, properly made up and stitched, were delivered at the building on the morning of the 1st of May, together with two copies elegantly bound in morocco, lined with silk, and with gilt edges, for presentation to Her Majesty and Prince Albert.

Such are the extraordinary circumstances under which the first edition of the Official Catalogue was prepared. That it should contain some errors will not excite surprise: it contained descriptions of articles which the describers neglected to send to the Exhibition, and in some cases, articles of great bulk could not be accommodated in the places assigned to them in the Catalogue. These, and errors of smaller note, were, however, corrected in the second edition.

The Official Catalogue consists of 320 pages, or 20 sheets of double foolscap folded into 8. It was sold within the building at one shilling—beyond its precincts at 15*d*. The statistics of the sale of this work belong to our last Section. For the use of our foreign guests, translations of the Catalogue in French and German were also sold at 2*s*. 6*d*. each.

Three mottoes selected by Prince Albert were appended to the Catalogue.

THE EARTH IS THE LORD'S, AND ALL THAT THEREIN IS:
THE COMPASS OF THE WORLD AND THEY THAT DWELL THEREIN.

Ne nostra, ista quæ invenimus, dixeris—
Insita sunt nobis omnium artium semina,
Magisterque ex occulto Deus producit ingenia.

Say not the discoveries we make are our own—
The germs of every art are implanted within us,
And God our instructor, from hidden sources,
Develops the faculties of invention.

Humani generis progressus,
Ex communi omnium labore ortus,
Uniuscujusque industriæ debet esse finis:
Hoc adjuvando,
Dei opt: max: voluntatem exsequimur.

The progress of the human race,
Resulting from the common labour of all men,
Ought to be the final object of the exertion of each individual.
In promoting this end,
We are accomplishing the will of the great and blessed God.

Section IX.—The Opening.

The interest naturally felt by the public in an undertaking in which the character of the British nation was, in so many respects, deeply involved, was constantly stimulated in various ways. The novel character of the building, the rapidity with which it was reared, as well as the marvellous effect of the exterior, could be judged of by a visit to Hyde Park. Those who enjoyed the rare privilege of admission to the interior, such as the reporters to the newspapers, told, from day to day, of the progress of the exhibitors, and even noticed, with some detail, many of the new and striking objects which were being arranged. These circumstances, together with the positive announcement that, notwithstanding the want of preparation in some of the foreign Sections, the building would be opened on the 1st of May by the Queen in person, tended to produce a world-wide excitement, which was, of course, most intensely felt in the metropolis. The admission to the building on the opening-day was by tickets only, and these were supplied by the Society of Arts, at the rate of three guineas for a gentleman, and two guineas for a lady; these tickets admitted the holders to the building, not only on the 1st of May, but at all other times when the public was admitted during the season allotted for keeping open the Exhibition.[1]

Although the admission to the opening ceremony was thus limited, yet the day was, by general consent, regarded as a universal holiday. At an early hour crowds of persons were seen wending their way to the great central point of attraction—the Crystal Palace, as people loved to call it, which, on this May-morn, stood out in its light blue-and-white attire, its brightly polished transept roof flashing in the sun, and the numerous small flags of all nations, with which its long lines of roof were decked, giving it a sparkling appearance;—all this made it look, not like the building of a northern clime, still less of smoky London, but one adapted to uninterrupted sunshine and never-fading foliage. Holders of season tickets were admitted between 9 o'clock and 11.30, A.M. Those who had seen the interior on the previous day, now expressed their astonishment at the order which, in one night, had been created out of an apparent chaos. The exhibitors had accomplished much of their work, but much remained to be done. The English department was tolerably perfect; the foreign was very defective: nevertheless, the foreign exhibitors managed, with much skill, to conceal their deficiencies. The whole area of the building had been rough, and encumbered with the signs of recent labour, and it was the business of the night to clear away all this, and to be ready to receive royal company on the morrow; the rubbish and litter of months of preparation were made to disappear in one night; the centre of the transept and the approach from the north were covered with red cloth; the path down the two sides of each nave covered with matting for the royal procession, and fenced off to prevent the pressure of the crowd. Seats were prepared for the company below, as well as in the galleries. Two elegant tiring-rooms were also rapidly erected for the Queen near the north entrance, and a beautiful silken canopy suspended at a height of thirty feet above the throne. A chair selected from the Indian collection served as a throne, and over it was cast a magnificent scarlet elephant-cloth, richly brocaded. The throne stood upon a raised dais, appropriately covered with the Ladies' Carpet,[2] and before it rose, to a height of twenty-seven feet, the splendid crystal fountain—the appropriate centre-piece of the Palace of Glass.

(1) On the 2d and 3d May, the price of admission was one guinea each person, from the 4th to the 25th May it was 5*s.*; and on and after the 26th May, 1*s.*, except on Fridays, when it was 2*s.* 6*d.*, and on Saturdays, when it was 5*s.*

(2) The *Ladies' Carpet* originated in a suggestion of Mr. W. B. Simpson, that a carpet should be made by ladies, to prove the possibility of equalling the looms of the Continent, and to point out a means of employing educated women who are wanting employment. With these views, a committee was formed, who obtained a design for a carpet 30 feet long by 20 feet wide, and 150 ladies undertook to work it, each lady taking a piece, together with her portion of the pattern which had been prepared by Mr. Simpson. The 150 pieces being completed, were worked and joined together. The design was by Mr. J. W. Papworth, and he very properly excluded from it those scrolls, monster flowers, and solid objects in relief, so common in carpets, which, if they really were the objects which they represent, would make it absolutely impossible to walk over them. His purpose was to produce the effect of a flat surface, the only objects in relief being flowers of the natural size, such as might be supposed to be scattered over the surface of a richly-inlaid floor. The entire number of squares in the canvas upon which the carpet was worked was 17,300,000,—a number which will give some idea of the labour required to produce this remarkable contribution to the Great Exhibition.

Soon after 9 o'clock, the Editor was among the throng of persons who were entering by the eastern door, the south or transept entrance being reserved for carriage visitors, the line of which, at this hour, extended considerably more than a mile towards the east. The seats filled rapidly, and although there were three hours of waiting before the ceremony began, that time was needed to accustom the mind to the sublimity of the scene. We then felt how different was the effect produced by the exterior and the interior of this marvellous building. When viewing the exterior of a Gothic cathedral, the mind can realize the interior; but this may be the result of past experience, which was wanting in the case of the Crystal Palace. The delight occasioned by its exterior arose from the skilful combination of a few simple elements—simplicity of design—vastness of extent—pleasing and harmonious decoration,—all this the mind could comprehend at a glance, and the satisfaction which that glance afforded was confirmed by a more deliberate survey. The interior, on the contrary, furnished as it now was by the contributions of the world, pleased by the vast variety and complication of the combining elements, which required time and study to make out. Now we could only judge of the general effect produced by some of the more striking elements, such as the naves, each, from its great length, skilful decoration, and shaded glass roof, appearing to fade into the blue distance; while bounding the two was the brilliant transept, now made still more brilliant by the rapid succession of visitors, in splendid and varied uniforms and costumes; the galleries were also lined with visitors, whose faces expressed admiration for the present, and hope for the future. In such a building, and at such a time, the mind was filled to overflowing; and an oppression of feeling was produced at the thought of having to study and describe these objects of art, science, and industry.

Long before the hour of noon, a large number of distinguished persons had taken their places around the throne. The members of the Royal Commission were, of course, there, waiting for their royal President; her Majesty's Ministers, the Executive Committee, the Ambassadors of various nations, the Lord Mayor, Sheriffs, and Aldermen of the City of London, the Commissioners of foreign states, formed various interesting groups. Mr. Paxton and Messrs. Fox and Henderson were the observed of all observers. A large number of the aristocracy were also present. The Archbishop of Canterbury, and several of the Bishops; the Lord Chancellor, and other legal dignitaries, wearing the costume which time and old associations have rendered sacred in the eyes of Englishmen; naval and military men, heralds, and beef-eaters, heightened by their costumes the brilliancy of the grouping. The transept galleries were occupied by choristers and numerous vocalists of eminence, as also by a selection of privileged visitors. At least 25,000 persons were present, all waiting, with eager intelligent expectation, for Her whose presence was alone wanting to complete the great gathering of all nations.

The cheers of the crowd and the roar of the cannon, made faint by the distance and the vast size of the building through which they feebly reverberated, announced the approach of the Queen. Suddenly a loud flourish of trumpets from the transept galleries, bespoke Her Majesty's entrance into the building. She was conducted at once to her robing-room, and after a short interval she appeared, accompanied by the Prince and two of the royal children, and attended by her Court, slowly coming forward under the great elm, between stands of choice exotics and tropical plants, fountains and statues, to the throne. Then arose that vast assembly, and gave a cheer such as only a free people can give; ladies waved their handkerchiefs, and all was stir and excitement. Just at that moment, too, the sun appeared from behind a cloud, and poured a flood of light upon the animated scene. Then burst out that wondrous tide of sound, in which thousands of voices prayed God to save our noble Queen; then came another cheer loud and prolonged —another, and yet another! At length impatient enthusiasm consented to be mute, and His Royal Highness Prince Albert having joined the Royal Commissioners, approached the Throne and read a Report of the proceedings of the Commission, in which after very briefly reciting the dates of the Royal Warrant and Charter, the proceedings founded thereupon at home and in the colonies, the selection of a site, the free admission of goods, the appointment of Local Committees, and the collection of subscriptions, His Royal Highness proceeded thus:—

The most energetic reports have been received from the governments of nearly all the countries of the world, in most of which Commissions have been appointed for the special purpose of promoting the objects of an Exhibition justly characterised in Your Majesty's Royal Warrant as an Exhibition of the Works of Industry of all Nations.

We have also to acknowledge the great readiness with which persons of all classes have come forward as exhibitors. And here again it becomes our duty to return our humble thanks to Your Majesty for the most gracious manner in which Your Majesty has condescended to associate yourself with your subjects, by yourself contributing some most valuable and interesting articles to the Exhibition.

The number of exhibitors whose productions it has been found possible to accommodate is about 15,000, of whom nearly one-half are British. The remainder represent the productions of more than forty foreign countries, comprising almost the whole of the civilized nations of the globe. In arranging the space to be allotted to each, we have taken into consideration both the nature of its productions and the facility of access to this country afforded by its geographical position. Your Majesty will find the productions of Your Majesty's dominions arranged in the western portion of the building, and those of foreign countries in the eastern. The Exhibition is divided into the four great classes of—1. Raw materials; 2. Machinery; 3. Manufactures; and 4. Sculpture and the Fine Arts. A further division has been made according to the geographical position of the countries represented; those which lie within the warmer latitudes being placed near the centre of the building, and the colder countries at the extremities.

The Prince then noticed the building; spoke of the shortness of the period in which it had been erected, its dimensions and adaptability to the purpose intended. He then proceeded :—

With regard to the distribution of rewards to deserving exhibitors, we have decided that they should be given in the form of medals, not with reference to merely individual competition, but as rewards for excellence in whatever shape it may present itself. The selection of persons to be so rewarded has been entrusted to Juries equally composed of British subjects and of foreigners, the former having been selected by the Commission from the recommendations made by the Local Committees, and the latter by the Governments of the foreign nations, the productions of which are exhibited. The names of these Jurors, comprising as they do many of European celebrity, afford the best guarantee of the impartiality with which the rewards will be assigned.

It affords much gratification that, notwithstanding the magnitude of this undertaking, and the great distances from which many of the articles now exhibited have had to be collected, the day on which Your Majesty has been graciously pleased to be present at the inauguration of the Exhibition, is the same day which was originally named for its opening, thus affording a proof of what may, under God's blessing, be accomplished by good-will and cordial co-operation among nations, aided by the means that modern science has placed at our command.

Having thus briefly laid before Your Majesty the results of our labours, it now only remains for us to convey to Your Majesty our dutiful and loyal acknowledgments of the support and encouragement which we have derived throughout this extensive and laborious task from the gracious favour and countenance of Your Majesty. It is our heartfelt prayer that this undertaking, which has for its end the promotion of all branches of human industry, and the strengthening of the bonds of peace and friendship among all nations of the earth, may, by the blessing of Divine Providence, conduce to the welfare of Your Majesty's people, and be long remembered among the brightest circumstances of Your Majesty's peaceful and happy reign.

Her Majesty in her reply spoke of her gratification in witnessing the successful results of the judicious and unremitting exertions of the Royal Commissioners, in the splendid spectacle by which she was that day surrounded. She then proceeded :—

I cordially concur with you in the prayer, that by God's blessing this undertaking may conduce to the welfare of my people and to the common interests of the human race, by encouraging the arts of peace and industry, strengthening the bonds of union among the nations of the earth, and promoting a friendly and honourable rivalry in the useful exercise of those faculties which have been conferred by a beneficent Providence for the good and the happiness of mankind.

His Grace the Archbishop of Canterbury then approached the throne, and offered up the following prayer to Almighty God for a blessing on the undertaking :—

Almighty and everlasting God, who dost govern all things both in heaven and in earth, without whom nothing is strong, nothing is holy; accept, we beseech Thee, the sacrifice of praise and thanksgiving, and receive these our prayers which we offer up unto Thee this day on behalf of the kingdom and people of this land. We acknowledge, O Lord, that Thou hast multiplied on us blessings which Thou mightest most justly have withheld. We acknowledge that it is not because of works of righteousness which we have done, but of Thy great mercy, that we are permitted to come before Thee with the voice of thanksgiving: and that, instead of humbling us for our offences, Thou hast given us cause to thank Thee for Thine abundant goodness. And now, O Lord, we beseech Thee to bless Thy work which Thou hast enabled us to begin, and to regard with Thy favour our purpose of knitting together in the bonds of peace and concord the different nations of the earth; for with Thee, O Lord, is the preparation of the heart in man. Of Thee it cometh that violence is not heard in our land, wasting nor destruction within its borders. It is of Thee, O Lord, that nations do not lift up the sword against each other nor learn war any more; it is of Thee that peace is within our walls and plenteousness within our palaces; it is of Thee that knowledge is increased throughout the world, for the spirit of man is from Thee, and the inspiration of the Almighty giveth him understanding. Therefore, O Lord, not unto us, not unto us, but unto Thy name be all the

praise. While we survey the works of art and industry which surround us, let not our hearts be lifted up that we forget the Lord our God, as if our own power and the might of our hands had gotten in this wealth. Teach us ever to remember that all this store which we have prepared cometh of Thine hand and is all Thine own. Both riches and honour come of Thee, and Thou reignest over all. In Thine hand it is to make great and to give strength unto all. Now, therefore, O God, we thank Thee; we praise Thee, and entreat Thee so to overrule this assembly of many nations, that it may tend to the advancement of Thy glory, to the diffusion of Thy holy word, to the increase of general prosperity, by promoting peace and good-will among the different races of mankind. Let the many mercies which we receive from Thee dispose our hearts to serve Thee more faithfully, who art the Author and Giver of them all. And, finally, O Lord, teach us so to use those earthly blessings which Thou givest us richly to enjoy, that they may not withdraw our affections from those heavenly things which Thou hast prepared for those that love and serve Thee, through the merits and mediation of Thy Son Jesus Christ our Lord; to whom, with Thee and the Holy Ghost, be all honour and glory.

At the close of this prayer the Hallelujah Chorus was sung by the united choirs of the Chapel Royal, St. Paul's Cathedral, Westminster Abbey, St. George's Chapel, Windsor, assisted by many of the pupils of the Royal Academy of Music, part of the band of the Sacred Harmonic Society, and many well-known public singers, both foreign and English. The sublime effect of this sacred chorus was in some respects peculiar. The vast size of the building afforded such ample space for the floods of sound thus poured out, that their intensity was lost before they had reached the extreme ends. Here the effect is described as being similar to that of a musical snuff-box. On approaching the transept the beautiful sounds became magnified; but in the transept itself, that loud and overpowering effect produced by a full band and chorus in an ordinary building was completely absent. Everything was subdued and softened by the enclosed space, of the vastness of which the mind was thus as accurately informed through the medium of the ear, as it had before been by that of the eye.

A procession was then formed in the following order :—

HERALDS.

Contractor, MR. HENDERSON. Architect, JOSEPH PAXTON, ESQ. Contractor, MR. FOX.

Superintendents of the Works,
C. H. WILD, ESQ. OWEN JONES, ESQ.

Financial Officer,
F. H. CARPENTER, ESQ.

Members of the Building Committee,
I. K. BRUNEL, ESQ. PROFESSOR DONALDSON.
CHARLES COCKERELL, ESQ.

Members of the Finance Committee,
SAMUEL PETO, ESQ. SIR ALEXANDER SPEARMAN, BT.

Treasurers,
BARON LIONEL DE ROTHSCHILD. SIR JOHN WM. LUBBOCK, BART.
WILLIAM COTTON, ESQ. ARTHUR K. BARCLAY, ESQ.

Secretary to the Executive Committee,
MATTHEW DIGBY WYATT, ESQ.

Executive Committee,
GEORGE DREW, ESQ. FRANCIS FULLER, ESQ.
C. W. DILKE, JUN. ESQ. HENRY COLE, ESQ.
LIEUT.-COLONEL WILLIAM REID, Royal Engineers, C.B.

Foreign Acting Commissioners,

Austria.—M. C. BUSCHEK and CHEVALIER DE BURG.
Bavaria.—PROFESSOR DR. SCHAFHAULT, M. THEOBALD BOEHM, M. SCHIEDMAYER, and M. HAINDL.
Belgium. — M. CHARLES CAYLITS and M. DE BROUCKERE.
Denmark.—REGNAR WESTENHOLZ.
Egypt.—CAPTAIN ABDUL HAMID.
France. — M. SALLENDROUZE DE LAMORNAIX.
Grand Duchy of Hesse.—M. RÖSSLER.
Greece.—M. RALLI.
HanseTowns.—M. PIGLHEIM.
Holland.—M. GOOTHENS, and M. J. DUDOK VAN HAL.
Northern Germany. — M. NOBACK.
Portugal.—M. F. J. VANZELLER, and M. ANTONIO VALDEZ.
Prussia.—BARON HEBELER.
Rome.—SIG. CARL. TRIBBI.
Russia.—M. GABRIEL KAMENSKY.
Sardinia. — CHEVALIER LENCISA.
Saxony.—DR. SEYFFARTH, LL.D., and M. GUSTAVUS DOËRTSLING.
Spain. — M. MANUEL DE YSASI, M. RAMON DE LA SAGRA, and M. RAMON DE ECHEVARRIA.
Sweden and Norway.—M. CHARLES TOTTIE.
Switzerland.—DR. BOLLEY and M. EICHHOLZER.
Tunis.—SIG. HAMDA ELMKADDEM. M. SANTILLANA, Interpreter and Secretary.
Turkey. — M. EDWARD ZOHRAB.
Tuscany.—DR. CORRIDI.
United States.—MR. EDWARD RIDDLE. MR. N. S. DODGE, Secretary.
Wurtemberg. —— MR. C. BRAND.
Zollverein.—M. BANRATH STEIN.

Secretaries to the Royal Commission,
E. A. BOWRING, ESQ. SIR S. H. NORTHCOTE, BART.
J. SCOTT RUSSELL, ESQ.

Special Commissioners,
DR. LYON PLAYFAIR. LIEUT.-COLONEL LLOYD.

Her Majesty's Commissioners,

MR. ALDERMAN THOMPSON. JOHN SHEPHERD, ESQ.
R. STEPHENSON, ESQ. PHILIP PUSEY, ESQ.
WILLIAM HOPKINS, ESQ. JOHN GOTT, ESQ.
T. F. GIBSON, ESQ. WILLIAM CUBITT, ESQ.
RICHARD COBDEN, ESQ. THOMAS BAZLEY, ESQ.
CHARLES BARRY, ESQ. THOMAS BARING, ESQ.
SIR CHARLES LYELL. SIR C. L. EASTLAKE.
SIR R. WESTMACOTT. RT. HON. W. E. GLADSTONE.
RT. HON. H. LABOUCHERE. LORD JOHN RUSSELL.
LORD OVERSTONE. LORD STANLEY.
EARL GRANVILLE. EARL OF ELLESMERE.
EARL OF ROSSE. DUKE OF BUCCLEUCH.

HER MAJESTY'S MASTER OF THE CEREMONIES.

FOREIGN AMBASSADORS and MINISTERS.

F. M. the DUKE of WELLINGTON, K.G. Commander-in-Chief. F. M. the MARQUIS of ANGLESEY, K.G. Master-General of the Ordnance

HER MAJESTY'S MINISTERS.

The BISHOP of WINCHESTER.

His Grace the Archbishop of Canterbury.

White Wands; viz.

Controller of the Household. Treasurer of the Household.

Vice-Chamberlain.

Lord Steward. Lord Chamberlain.

Garter Principal King at Arms.

His Royal Highness PRINCE ALBERT, leading Her Royal Highness the Princess Royal. The QUEEN, leading His Royal Highness the Prince of Wales.

His Royal Highness the Prince of Prussia. Her Royal Highness the Duchess of Kent.

His Royal Highness Prince Henry of the Netherlands. Her Royal Highness the Princess of Prussia.

His Royal Highness Prince Frederick William of Prussia. Her Royal Highness Princess Mary of Cambridge.

His Serene Highness Prince Edward of Saxe-Weimar. His Royal Highness the Duke of Cambridge.

Mistress of the Robes.

Lady of the Bedchamber, Marchioness of Douro. Lady of the Bedchamber in Waiting.

Maid of Honour in Waiting. Maid of Honour in Waiting.

Bedchamber Woman in Waiting. Lady Superintendent, Lady Caroline Barrington.

Foreign Ladies, and Lady in Attendance on H. R. H. the Duchess of Kent.

Gold Stick in Waiting. Master of the Horse.

Groom of the Stole to H. R. H. Prince Albert.

Captain of the Yeomen of the Guard. Captain of the Gentlemen at Arms.

Master of the Buckhounds.

Lord of the Bedchamber to H. R. H. Prince Albert in Waiting. Lord in Waiting upon the Queen.

Groom of the Bedchamber to H. R. H. Prince Albert in Waiting. Groom in Waiting upon the Queen.

Clerk Marshal.

Equerry to H. R. H. Prince Albert in Waiting. Equerry to the Queen in Waiting.

Gentleman Usher. Gentleman Usher to the Sword of State. Gentleman Usher.

Silver Stick in Waiting. Field Officer in Brigade Waiting.

The Gentlemen in Attendance upon their Royal Highnesses the Duchess of Kent, the Duke of Cambridge, and the Prince and Princess of Prussia.

Heralds.

The procession first advanced towards the west end of the nave along the north side, cheered in its progress by a dense wall of loyal subjects and admiring foreigners, and as it neared the immense mirror which formed a conspicuous boundary to the western end, the large organ in the gallery opened its mighty voice of greeting. Then moving round the model of the Liverpool Docks, the procession returned to the transept by the south side of the nave, and passing along the south end of the transept, it glided into the Foreign department of the Exhibition. The great French organ sounded the note of welcome, which was next taken up by the Erfurt organ, and as the pageant rounded the eastern end of the building, the bands of the Coldstream and Scots Fusilier Guards struck up their spirit-stirring strains. The return along the north side of the nave was welcomed by the enthusiastic cheering of foreigners, and at length having completed this truly royal and peaceful progress, the Queen returned to her position in the transept, when the Marquis of Breadalbane announced in a loud voice, that the Queen declared the Exhibition open. A flourish of trumpets re-echoed the fact to the assembled multitudes; the choir opened the noble strains of the National Anthem; the Royal Family attended by the Court withdrew from the building; the barriers which kept back the impatient throng were removed, and the visitors poured over every part of the building with all the eagerness of long restrained but now liberated curiosity.

Such is a very feeble description of this great and solemn ceremony, which the imagination freed from the encumbrance of words is alone adequate to realize. There is something very touching in great assemblies of human beings, and the present was peculiarly so. There were five-and-twenty thousand people assembled in one building, for the purpose of dedicating to the Almighty a work begun in peace and good-will, and intended for the benefit and instruction of mankind. It was impossible to take part in so sublime an undertaking without emotion, without an elevation of the faculties to Him who "giveth to all life, and breath, and all things; and hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation; that they should seek the Lord, if haply they might feel after him, and find him, though he be not far from every one of us: for in Him we live, and move, and have our being." (Acts xvii. 25—28.) The most indifferent spectator must have felt emotion at such a time, and, explain it how he

may, he is benefited and improved by sharing in the unity of purpose of so vast a multitude, worthily headed by the Sovereign of the land and her illustrious Consort, supported by the Ministers of the State, by the great and chosen of the land, by the rank, genius and intellect also of other lands. Every one present must have felt the power of the enthusiastic loyalty of the people without and within the building, manifesting itself, as it evidently did, not in a blind idolatry of the person of the Sovereign, but in love to her as the representative—the personification of peace, liberty and security. No sovereign attended by armies of soldiers could have commanded that cordial cheer prolonged from mouth to mouth, which marked the progress of the Queen; none but a people in the full enjoyment of free institutions could have raised that shout which greeted her entrance; none but a free people could have spontaneously mingled thousands of voices in that tuneful prayer—*God save the Queen.*

But the Exhibition is open: the barriers are removed, and we commence our leisurely stroll through the building, and at every step recollections are awakened and associations formed in rapid succession. Here is a noble statue, exciting our patriotic gratitude to the honest statesman who served his country well. Here, resting on his sword, and calmly surveying the scene before him, is the gallant colonel, whose enemies recorded his death as that "of a man so religious, and of that prudence, judgment, temper, valour, and integrity, that he hath left few his like behind." There stands the outward form of that mighty genius to whose teaching England owes a debt the magnitude of which who can limit? for who can say how much that is generous in the English character, how much of the honesty of purpose, of the hatred of oppression, of the reverence for divine things, and of the religious and political independence prevailing among our people, we owe to the teaching of Shakspeare? Many persons who have refused to listen to higher teaching have consented to be taught by him. We stroll on, and pause long before that group of which the principal figure is one worthy of all honour, reverence, and love; a man who combined the exalted devotion of the Puritan with the graceful accomplishments of the Royalist, without partaking of the fanaticism of the one or the profligacy of the other; noble, as a patriot, as he was great, as a poet; deeply read in classical and biblical literature, well versed in the science of his own and of other times, a great master of style, both in poetry and prose: we see him before us—wisdom at one entrance quite shut out—with his daughters at his feet, rendering permanent that splendid poem which is flowing from his lips. But we must not pause: we can only, on this bright holiday, just glance at forms of classic beauty suggested by the visions of the poet; gaze for a moment tenderly upon the sweet form of her who is advancing to meet us with the well-known words, "*Guardami ben; ben son, ben son Beatrice.*" But we must linger awhile before that group which tells its own terrible story with such painful fidelity. We fancy we hear the shriek of terror of that horse under the close grasp of the tiger, and see the uplifted spear cleave the skull of the savage animal. We pass by the beautiful stained glass window, in which the artist has endeavoured to show his respect for the great Dante; we admire the beautiful paintings on porcelain, the pictures in mosaic and fresco, the marvellous creations in tapestry, the artificial flowers, which rival the works of nature, skilfully imitating her decay as well as her blooming vigour:—these, and a thousand other objects, light up, adorn, and relieve the more ordinary productions of industry, which, in their turn, are well calculated to interest and inform, and to recall to the man of science many a tale of patient toil, and of genius strong in its own self-reliance. Here he sees the successful results of science applied to the useful arts; or, the equally successful results of the useful arts which preceded by many centuries the birth of science. How strange, too, are the contrasts in things whose objects are apparently the same! Here we have a huge clock whose iron tongue informs a whole city of the progress of time; there we have a watch which marks its course on the top of a pen-holder, or in one of the small ornaments of a lady's bracelet: the hydrostatic press which balanced one of the tubes of the Britannia Bridge, weighing 1,400 tons; a chemical balance which weighs to the $\frac{1}{1000}$th of a grain: the cable which holds a man-of-war safely to her moorings; the cotton yarn, 1,026 miles of which are required to make up a pound weight: the small hammer which rivets a delicate piece of jewellery; the steam-hammer which falls down with a force of hundreds of tons: the pair of scissors weighing a grain; the ponderous

shears by which iron is cut with as much ease as if it were paper: iron wire almost invisible from its tenuity; a cylindrical bar of rolled iron, 7 in. in diameter, 20 ft. 1 in. long, and weighing 1 ton, 2 cwt. 3 qrs. 12 lbs.: the tusk of an elephant, weighing 139 lbs.; and an unbroken veneer of ivory, 41 feet long, and 14 inches wide. Such are a few of the contrasts, noted down almost at random: the metamorphoses are even more astonishing. A quantity of old rope, mouldy and decayed, the material which furnishes the beautiful paper used in the printing of pottery ware; a hard, shrivelled, worthless-looking piece of membrane, converted by the gold-beaters' skin maker into a beautifully delicate tissue; the dark and worthless-looking alum shale, converted into magnificent crystals of alum: these and a thousand other examples show that materials which are worthless only when they are in improper hands, become transmuted by the chemist into products of great commercial value.

The immense number of objects so skilfully grouped, derive some of their fascination from the building in which they are exhibited, and the mode in which they are lighted. The mind is always pleased with order and classification, especially when their advantages are apparent, which is not always, or indeed often the case without considerable study. A person who is not a botanist or a mineralogist could not admire, because he could not discern, the advantages resulting from a scientific classification of plants or minerals. But in the Great Exhibition the classification admits of being comprehended without much previous study. It was both pleasing and instructive to trace the raw cotton from the bale to the finished yarn, through that wondrous series of machines, which with excellent taste and judgment were exhibited in action just as they are worked in the factories at Manchester, and watched by the same attendants in their usual working dresses. It was, we say, instructive to watch these machines, which apparently excel the human head in ingenuity as they certainly excel the human hands in precision, regularity, and endurance; and then to go to a neighbouring portion of the building and find the cotton yarns, threads, and fabrics, with a variety of instructive specimens illustrating progressively the results of bleaching, dyeing, and printing. There was much to be learned in watching the variety of improved machines busily at work in breaking and heckling flax, and then to step across the building and examine the large and variegated display made by the linen manufacturers. Indeed, flax was much more worthily represented in the British department of the Exhibition than its more powerful rival cotton. It was also a pleasant satisfaction to the mind to find the cutlery and other productions of Sheffield all collected in a court by themselves; the varied products of Birmingham were also similarly collected; agricultural implements made a large and striking display; wheel carriages also collected together gave the rare opportunity of studying the immense variety of vehicles to which our useful servant the horse is yoked. This instructive system of grouping was as far as possible followed in respect of British products. A totally different system was observed for our Colonies, but one producing equally harmonious and instructive results. The industrial products of Canada, for example, were collected in one court, before the entrance of which, as if to guard its approach, stood two noble deer, admirably stuffed. Passing by the comfortable sleigh which reminded one of a long winter and admirable roads made by the snow, where roads at other seasons of the year scarcely exist, we find ourselves in the midst of a motley collection of raw and manufactured produce belonging to all the kingdoms of nature; much that is quite new and singularly interesting from its novelty as well as intrinsic value; something also that is old, and something common to all the members of the human family. But the great value of such a collection (which once made ought never to have been dispersed, but cherished with the love that we feel towards a valuable book or other mute intellectual friend), the value of such a collection is, that we have here, focalized as it were, the industrial resources of a great country. The man of science and the merchant, the naturalist and the statesman, can in one visit to this single collection learn more of the industrial resources of Canada than could be obtained from months of study in a library, or correspondence with Canadian people. Of course the same or similar remarks apply to the other collections, not only of our colonies, but of our neighbours the French and the Germans, and of all who contributed. Indeed we know of few things more suggestive, of no museum more instructive, than one of these foreign courts, however small and apparently

insignificant. Where else, for example, could one learn respecting Turkey that rich store of facts which a few hours spent among her contributions was so well calculated to afford? In what book of travels, or in what naturalist's library, must one look for the strange contrasts presented by Tunis; in which the barbaric splendour of dress and attention to personal appearance showed, as well as the rude utensils and clumsy household contrivances, a people who from some mysterious cause had some centuries ago advanced up to a certain point of civilization, and then suddenly stopped. Turkey and Egypt are equally instructive and suggestive. There are the skins of the water carriers; the figs which are sold in the name of the Prophet; the toasted pips of the melon, which are said to be consolers of the embarrassed; the cotton stuff made by machinery which is set in motion by a bull, and hawked about the streets of Cairo as "The work of the bull, O Maidens!" the flowers of the henna tree announced for sale as "odours of Paradise."

On the opening day we must not look too closely into the Foreign department, for there is assuredly enough for months to come to occupy the most industrious and frequent visitor. Yet the truth must be told. France is greatly in arrear. The Zollverein has been slow in her movements, but has managed to make a large and splendid display at the opening; the most striking portion of the Austrian contributions are ready. Hamburg and Switzerland are punctual and business-like, as becometh a commercial people; Russia has not opened her splendid malachite doors, but much of her raw material is laid out in order.[1] The United States has not filled out very well, a circumstance which has excited much unnecessary criticism, for it was forgotten, or at least was not mentioned, that the States made no claim for space, but took what had been allotted to them, and made the best use of it which they could.

Such are a few of the thoughts which the first day's stroll in the Great Exhibition suggested to our mind. The report of our next visit will be more methodical, but still only cursory. Our purpose is first to bring together a few notes on the more remarkable objects exhibited in each of the thirty classes, so as to give the reader who has not visited the building some idea of its marvellous contents, and of their arrangement and general effect; and secondly, to supply, in conjunction with our Cyclopædia, for the use of those who did, as well as for those who did not, visit the Exhibition, a permanent record thereof, and of the state of the useful arts and manufactures at the present time. We shall then conclude with a retrospective view of the season, which will lead us into a number of curious and interesting statistical details.

Section X.—Raw Materials Exhibited. 1. *Mineral.*

The Raw Materials of the Great Exhibition were among the most interesting objects of the whole of that industrial display. In some departments of industry they formed a complete series of illustration; in other departments they were defective; in all they were eminently suggestive. It was scarcely possible to study them, without feeling a strong desire to preserve them as the nucleus of a museum of the raw materials of the world. Not only would such a collection, carefully selected and scientifically arranged, give positive information respecting the natural history of the country which supplied them; it would not only instruct the chemist and the botanist, the geologist and the mineralogist, but would be eloquent to the merchant and the manufacturer. He would know to what part of the world it would be most advantageous to send for a supply of a certain raw material; he would be able beforehand to judge of its quality, its price, and various other particulars; he would also know what to send to such a country in exchange for its raw produce. Finding neither coal nor iron among the collection of a particular country, he would conclude that many of those varied products which the coal-fed steam-engine supplies, would be acceptable to the people of that country. Such a collection,

(1) It may be mentioned among the gossip of the day, that a French hair-dresser, at Odessa, is said to have petitioned the Russian Commissioner to try his eloquence in inducing her Majesty to postpone the solemn opening on the 1st of May for the space of three days, to enable him to complete his six interesting wig blocks for the occasion.—Another piece of gossip had reference to a direction on one of the foreign packages, which ran thus:—

"Sir Vyat and Sir Fox Enderson Esqvire
Grate Exposition Park of Hide, at London.
Glace softly to be posed vpright."

possessed by the more civilized or more richly endowed country, would prove eminently advantageous to the less civilized country, whose raw material was more scanty, or of a different kind. An intercourse thus brought about, is well adapted to the nature and wants of man; it stimulates his industry, tends to promote peace and good-will, diffuses knowledge, serves the cause of religion, advances civilization, and keeps his faculties usefully and healthfully employed. For this purpose it seems to have been wisely ordained, that the gifts of nature are difficult, but not too difficult, to secure. The coal, the iron, and other useful metals; the stones, the clay, the slates; the corn, the flax, the cotton, cannot be obtained without an amount of labour, which keeps man constantly working for his fellow-man; and the result is, advantage to both.

A very large proportion of the industrial employments of the world, consists in the preparation of raw materials for other branches of industry. Every employment has its own peculiar *raw material*, by which term we do not always mean a material rough from the bowels of the earth, from the depths of the ocean, or the recesses of the forest. The finished product of one occupation, may be the raw material of another. The nodules of clay iron stone, the limestone flux, and the coal or coke fuel, are the raw materials of the iron smelter; pig-iron is his finished product, and a vitreous slag his *refuse.* To the refiner, pig-iron is a raw product, which by puddling, beating, and rolling, becomes bar-iron, which to him is a finished product, to become in its turn a raw material to other branches of industry. These illustrations might be carried to any extent, but enough has been said, if we form in our own minds a clear definition of the term, raw material. Any substance in its natural state, or manufactured, which is capable of being further manufactured, or which forms the basis or ground-work of any other branch of industry, is a raw material.

We have already (Section II.) pointed out as one of the causes of the prosperity and greatness of our country, the possession of an abundant supply of mineral raw materials. Indeed, this is one of the circumstances which strikes with astonishment the intelligent foreigner who first makes acquaintance with our island. In the course of a few days he is able to survey a display of mineral wealth, which for richness and variety cannot be equalled in any other part of the world of similar extent. Instead of the widely extended plains which occupy the traveller many wearisome days to traverse, we have in Britain the ever recurring variety of hill and valley, sea-coast and plain. On his first arrival he sees the magnificent chalk cliffs of Dovor, which have given to *Albion* her name. Other parts of our coast present another formation,—that of the conglomerate red sandstone, which forms splendid and picturesque contrasts with the green colour of the sea, stretching out in bold promontories, forming conical rocks hollowed out by the action of the waves, and immense caves formed by the violent and ceaseless dashing of the surge, as at Exmouth, Dawlish, and Teignmouth. Or the same rock may be seen alternating with strata of marl, as at Lyme Regis, which, breaking down easily, reveals the remains of the huge Ichthyosauri of the primitive world. Other parts of our coast present the large, massive, lowering peaks of primitive granite, as seen in the precipices of Cornwall; or on the western coasts of Mull, and at Iona, projecting boldly into the sea in the form of rounded masses. A fourth formation consists of the Plutonian trapps, which are either driven up in thick masses, as in the neighbourhood of Edinburgh, and the Frith of Forth, or, like magnificent basaltic columns springing from the bosom of the sea, exhibit the fantastic pillars and caves of Staffa.

A scientific foreigner, who perambulated our island a few years ago, spoke of the geological distinction of England, in containing four such peculiar formations of the earth's surface, and in such magnitude and beauty, comprised within so limited a space. "They are," he says, "not to be found in such a union in any other portion of Europe."[1]

A scientific authority of our own country,[2] places in a striking light the value and variety of our mineral possessions, by supposing three foreigners to land on our island, and to pursue different routes. If the first, landing at the extremity of England, were to traverse the whole of Cornwall, and the north of Devonshire; and crossing to St. David's, should make the tour of

(1) England und Schottland im Jahre 1844. Von Dr. C. J. Carus. Berlin, 1845.

(2) Buckland, Bridgewater Treatise.

all North Wales; and passing thence through Cumberland by the Isle of Man, to the south-western shore of Scotland, should proceed either through the hilly region of the Border counties, or along the Grampians, to the German Ocean, he would conclude from such a journey of many hundred miles, that Britain was a thinly peopled, sterile region, whose principal inhabitants were miners and mountaineers. If the second foreigner should arrive on the coast of Devon, and cross the Midland counties from the mouth of the Exe to that of the Tyne, he would find a continued succession of fertile hills and valleys, thickly overspread with towns and cities, and in many parts crowded with a manufacturing population, whose industry is maintained by the coal with which the strata of these districts are abundantly interspersed. Let the third foreigner travel from the coast of Dorset to the coast of Yorkshire, over elevated plains of oolitic limestone, or of chalk; without a single mountain, or mine, or coal-pit, or any important manufactory, and occupied by a population almost exclusively agricultural. Now, suppose these three strangers were to meet at the termination of their respective journeys, how different would be the accounts presented of the actual condition of Great Britian. The first would represent it as a thinly peopled region of barren mountains; the second, as a land of rich pastures, crowded with a flourishing population of manufacturers; the third, as a great corn-field, occupied by persons almost exclusively engaged in the pursuits of husbandry. These dissimilar conditions of three great divisions of our country result from differences in the geological structure of the districts through which our three travellers have been conducted. The first will have seen only those north-western portions of Britain, that are composed of rocks belonging to the primary and transition series; the second will have traversed those fertile portions of the new red sandstone formation, which are made up of the detritus of more ancient rocks, and have beneath and near them, inestimable treasures of mineral coal; the third will have confined his route to wolds of lime-stone and downs of chalk, which are best adapted for sheep-walks and the production of corn.

The mineral wealth thus indicated to our three travellers was illustrated in the Great Exhibition by a rich variety of specimens, finished works, models, sections, maps, and tools. To commence with the granite, which forms the floor-work of our globe, and, as a general rule, the basis of all other strata, whose economic applications meet us at every turn—in our bridges, our streets, and in some of the public monuments which we desire to bequeath to posterity. Granite is a very beautiful rock, and its composition is in many respects remarkable. In its typical and most abundant form it consists of quartz, felspar, and mica, either in distinct crystals, or filling interstices between crystals. The term granite, however, has a much more extensive signification. Hornblende is sometimes found in granitic rocks, and the aspect of granite is in some cases greatly modified by such minerals as actinolite, chlorite, talc, compact felspar, steatite, garnet, zircon, &c. Granite also varies considerably in colour: the felspar may be red, grey, yellow, white, or green; the quartz is usually clear white or grey; the mica may be black, grey, white, brown, and in various degrees silvery; the hornblende is dark green or black. The mica and felspar are crystallized, often beautifully so; the quartz commonly fills the interstitial spaces left by the mica and felspar. Granite, as its name implies, shows the *grains* of its component parts. These vary greatly in size. In the Rubieslaw granite, near Aberdeen, the mica forms laminæ some inches across; but in the granite of Cornwall, Skiddaw, &c., it exists in small plates. In *graphic* granite the felspar is a crystalline mass, in which the angular arrangement of the quartz makes the surface appear as if covered with small oriental characters, whence the name: large detached crystals in the granites of Shap and Ben Nevis make those rocks porphyritic; but in some of the building granites of Aberdeen, all the ingredients are in small grains. The proportion of the ingredients in typical granite is also subject to considerable variation. In some cases the mica is absent, or is replaced by hornblende. Some of the most remarkable granitic mixtures have been tabulated as follows:—

Binary Granite, of two ingredients, such as *felspar* and *mica*, or *quartz* and *mica*, either equally blended, as in Muncaster Fell, Cumberland; or in segregated portions, as the graphic granite: *quartz* and *hornblende; felspar* and *hornblende*.

Granite of three ingredients, or the typical varieties.—*Quartz, felspar*, and *mica* uniformly blended; or with distinct additional crystals of felspar, in which case it is called *porphyritic granite. Quartz, felspar*, and *hornblende* form *syenite. Quartz, felspar*, and *mica*, or, instead of the mica, *chlorite* or *talc*.

GRANITE OF FOUR INGREDIENTS.—*Quartz, felspar, mica,* and *hornblende,* or *actinolite,* also forming syenite. *Quartz, felspar, mica,* and *compact felspar,* or porcelain clay. *Quartz, felspar, hornblende,* and *chlorite,* or steatite.

The granites, according to this extended view, were not very well illustrated in the Great Exhibition; that is, they were not arranged in a series adapted to their geological and industrial importance. There were, however, some noble specimens, in the form of columns and obelisks, among which must be noticed a column and pedestal, 30 feet high, from the Cheesewring granite quarries, near Liskeard, in Cornwall, and forming one of the striking objects outside the building.[1] The Cheesewring is so named from a pile of granite blocks on the summit of a hill, which from a distance resemble cheeses. This pile is represented in Fig. XLIX.; and in Fig. L. is a similar neighbouring pile, which forms the crest of Kilmarth Hill, at an elevation of 1,200 feet. Such fantastic shapes are caused by the disintegrating action of rain, frost, and wind, and are very common in rocky districts. A comparison of the granites of Scotland, Cornwall, the Channel Islands, and of some of the foreign states, exhibited some marked contrasts, as did also the Cornish elvans,[2] porphyries, and greenstones: there was also some excellent green porphyry from Ireland. Many of the stones exhibited have not been much in request for building and ornamental purposes; and we cordially repeat the suggestion of a writer in the *Times*, that, in some of our future public buildings, or first-class houses, the basements be constructed of granite, with imposts and string courses of porphyries and greenstones, relieved with panels of some lighter stone. The effect of such a combination would not only be pleasing, but durable; and, once adopted, would, we should hope, supersede the mouldering stucco which is now so common. The interior of noble galleries might be lined with porphyry; an example of which was begun by the late Mr. Treffry, at his beautiful castle of Place, near Fowey. When the writer visited Cornwall, a few years ago, Mr. Treffry explained to him his machinery for cutting the porphyry into slabs and polishing it. Slabs of black, of red, and of green porphyry were exhibited, and also a tessellated porphyry table, containing 54 specimens of indigenous stones, raised in the parish of Withiel from a porphyry quarry which has been worked for fourteen or fifteen years. It was polished in the mills at Fowey Castle Mine. The Penzance Serpentine Company have also been brought into prominent notice by their beautiful display of serpentine, which seems to be well adapted to ornamental purposes.

Fig. XLIX. THE CHEESEWRING.

Fig. L. KILMARTH ROCKS.

Connected with the granite of Cornwall is the *kaolin,* or china-clay, so valuable in the manufacture of the finer descriptions of china and earthenware. [See CLAY, p. 375.] Numerous specimens of this fine clay were exhibited. In Cornwall it is obtained chiefly from the St. Austell granite, and also from Tregorming Hill, to the south of Helstone. In Devonshire, the southern granite of Dartmoor also supplies this valuable raw material. The composition varies with the locality; but the average of the best Cornish clay consists of alumina 24.6, silica 44.30,

(1) Some of the objects exhibited, from the large size, from their late arrival, or from some special adaptability, were arranged in the two enclosed spaces at the eastern and western ends of the building.

(2) *Elvans* are porphyritic dykes, which traverse many parts of Cornwall, and supply the chief building stones of the districts where they occur.

lime, magnesia, and potash, 1.60, water 8.74. The pure kaolin of Dartmoor consists of alumina 36.81, silica 44.25, lime, magnesia, and potash 2.20, water 12.7. An inferior quality of this clay is largely used by the paper-makers and calico-dressers, in order to give weight and body to their goods.

Scotland, Wales, and Cornwall also supplied abundant specimens of SLATE. Some of the slabs were from 10 to 15 feet long, and from 3 to 6 feet wide, and varying from a coarse grain to a fine laminated texture. Some were polished and ornamented, and formed into table-tops, chess-boards, and other articles; but the effect of ornamented slate was by no means good. The slabs were used for building purposes, such as strong-rooms, powder-magazines, larders, venison-houses, and partitions to rooms; also for the floors and compartments of public baths, chimney-pieces, cisterns, and filters. A head-stone for a grave, a clock-face, sinks, and pickling-troughs, are a few of the articles made of slate. Mr. Stirling's collection gave a good idea of the best qualities of slate introduced into the London market. The chief slate quarries are at Delabole, in Cornwall; Festiniog, Penrhyn, Llanberis, &c. in Wales; Westmoreland, and Lancashire. From 30,000 to 40,000 tons of slate per annum are at present consumed in London. One-third of this quantity is in slabs, and the rest roofing-slates, of which there are 9 sizes, called respectively *ladies*, *countesses*, of which there are 3 sizes, *duchesses*, two sizes, *queens*, *rags* and *imperials*. From *ladies*, 16 in. by 8, to *duchesses*, 24 in. by 12, slates are sold per thousand (of 1,200); but above that size by the ton. The *ladies* weigh 25 cwts. per thousand, and the *duchesses* 3 tons. The regular sized slabs vary from 1 to 6 feet in length, and 1 to 3 feet in breadth. The Delabole Slate Company exhibited a slate cistern of the capacity of 2,000 gallons.

The COAL of the British Islands was admirably represented in the Great Exhibition. The Committee of the Coal Trade of Northumberland and Durham forwarded maps and sectional drawings of their coal-field, showing the pits and railways, faults, and other remarkable interruptions; also a synopsis of the coal-seams; a working plan of a colliery, showing the system of working and ventilation. A large collection of the fossil plants of the coal formation were of great interest and value. There were also various specimens of household, coking, manufacturing, and cannel coal. Coal from the carboniferous limestone formation; specimens of the strata and rocks of the coal formation, and of the carboniferous limestone formation; specimens of coke; safety lamps used in the collieries;[1] sectional drawings of Walbottle Colliery engine-pit, showing the engines, pumps, &c.; also a model, showing the method of drawing coals from the mine, and screening the same at the surface; models showing the mode of ventilating coal-mines, and of an underground ventilating furnace, were also exhibited.[2]

The productive coal area of the Newcastle coal-field has been calculated at 360,000 acres in Durham, and nearly 150,000 in Northumberland. Of this quantity, about 67,000 acres have been worked. The average thickness of the seams is about 12 feet: an acre contains 4,840 square yards, and each cubic yard of coal weighs about a ton. This coal-field has therefore contained upwards of 10,000,000,000 tons of coal, of which about one-eighth has been consumed. The present annual consumption is estimated at 10,000,000 tons. The coal is all bituminous, and the qualities vary according to the proportion of bitumen in each. There are three qualities; viz. the common *caking* kinds, coarser kinds called *splint*, and *cannel* coal. The average quantity of gas from the caking coals is about 8,000 cubic feet per ton; the weight of coke being from 10 to 12 hundredweight. Cannel coal yields from 10,000 to 12,000 cubic feet of gas per ton.

(1) Mr. Watson, of Newcastle-upon-Tyne, exhibited one of the old steel mills used for producing light before the introduction of the safety lamp. This mill consists of a disc of steel mounted in a frame upon a horizontal axis: on turning the disc rapidly round by means of a handle, the edge was made to strike against a piece of flint, thereby producing a succession of sparks which were not sufficient to ignite the fire-damp. The light thus afforded was very feeble, and an attendant was required to keep it in action.

(2) In the ventilation of coal-mines, as explained in our article COAL, the direction of the ventilating current is regulated, and the fire-damp prevented from extending, by stopping up certain *ways* with doors, which are attended by boys, whose duty it is to close them after the passage of a wagon; but the boys are apt to fall asleep, and leave the doors open. A simple but most valuable contrivance, invented by Mr. Robert Mills, of Foxhole Colliery, near Swansea, was illustrated by a model of an apparatus for opening and closing doors in mines by a reversion of levers, one opening and the other closing the door, on each side of the door, and whether worked by the carriage drawn by a horse, or pushed by a man or boy, the action is the same. In the colliery where this apparatus has been used, there has not been an explosion of gas for twenty-two years; and we were informed that the coal-owners of the north were so much struck with its utility that they determined at once to adopt it. This is one of the numerous instances of the value of the great industrial congress: men from different parts of the world compare their several inventions, and thus mutually benefit each other and the public at large.

The ten-yard or thick coal of Staffordshire was admirably illustrated. Large specimens of this were arranged in the enclosed space outside the building, at the western end. Messrs. Bagnall and Gesson exhibited a fine column, showing the different working seams as they exist in vertical section. Mr. Round, of Hange Colliery, Tipton, also sent a complete section of the seam in the form of a block, 18 feet in circumference, and weighing 5 tons: it was the largest specimen that could be brought out of the mine up a 7-feet circular shaft. The rope and chains used in lifting it were also exhibited, and it was stated that only the ordinary machinery employed in the colliery was used. Messrs. Haines, Richard & Sons, of Denbigh Hall, Tipton, exhibited a specimen of the thick coal, 9 feet 6 in. high, 21 ft. 10 in. in circumference, and weighing 13 tons. It was conveyed 70 yards underground to the bottom of the shaft, and raised from a depth of 165 yards by the steam-engine in ordinary use.

The Barnsley coal was admirably illustrated. This coal comes from the great central coal-field of South Yorkshire, Nottingham, and Derbyshire, a district extending from Leeds to Nottingham, and including 650,000 acres of coal-field. The qualities are bituminous, or household coal, steam-coal, cannel, and anthracite; but the qualities vary in different localities. Earl Fitzwilliam exhibited a complete section of the thick bed from the Elsicot Colliery, showing the different portions applicable for steam-engines, manufacturing purposes, and domestic uses. In this field is also found that curious variety called *iridescent* or *peacock* coal, from the circumstance of its fracture reflecting a variety of colours. A column of this coal, from the old Silkstone colliery, was exhibited. It has not been decided whether the iridescent appearance arises from a thin film of foreign matter deposited on its surface, or from the mechanical condition of the surface itself, as in mother-of-pearl.

The great coal-field of South Wales was fairly represented. This valuable field presents nearly 1,000 square miles of productive coal area; it comprehends *anthracite* or stone-coal, and *bituminous* coal, and also an intermediate semi-bituminous variety, termed *steam-coal.* The line which separates the bituminous from the anthracitic coal, is nearly coincident with the Neath Valley, the anthracite portion extending to the west. The anthracite has not been in use many years; but it is now of great value for certain special purposes, among which, we may refer to the skilful and ingenious application of it in the roasting of copper ore [see Copper, page 429]. It sometimes contains as much as 92 per cent. of carbon; 1 lb. of it will evaporate 10 lbs. $8\frac{1}{2}$ oz. of water, while the best bituminous coal evaporates not more than 8 lbs. A large block of anthracite from Cwmllynfell, in the Swansea Valley, was exhibited. The Duffryn steam-coal, which was exhibited, is rather soft; it burns clearly without smoke, it does not cake, and leaves only a little white ash; these qualities fit it for the purposes of steam navigation, whence the name applied to it. A noble column of steam-coal, weighing 16 tons, was also exhibited from the main coal of the Flintshire coal-field.

Cannel coal, from the Wigan coal-field, was exhibited, together with various vases and ornaments turned out of the same. This coal is of fine quality and takes a high polish. The Wigan coal-field is a portion of that known as the Lancashire and Cheshire, or Manchester, great coal-field, the productive coal area of which is nearly 400,000 acres; it is divided into three principal portions, of which, the middle one includes the thick coal-seams. The principal varieties of coal are a good caking coal and a valuable bed of cannel.

The coal region of the south of Scotland was represented by a block of coal raised from the lowest stratum of the Victoria coal-pit, in Renfrewshire. There were also specimens of the alum ore, or schist, which lies immediately above the coal, and of the limestone, which lies immediately above the alum ore. Alum ore, in process of decomposition, and alum made from the ore, were also shown. [See Alum, page 39.] This colliery, which is 173 fathoms deep, is in the great coal region of South Scotland, which is supposed to comprise more than a million acres of productive coal. In the Renfrewshire coal-field there are 10 seams of coal separated by thin bands of clay; the coal is covered with a thin bed of alum slate (from which alum is manufactured) and is mixed with iron pyrites. Valuable bands of iron-stone and some limestone occur near the coal. Specimens of the principal iron-stone beds, fossils and crystals, found in this extensive mineral field, were exhibited. The Lanarkshire coal-field also contributed speci-

mens of its coal, iron-stone, and limestone, the three grand materials required in the production of iron, and associated together in vast abundance in this country.

Ireland sent a specimen of anthracite from the coal-fields of Kilkenny, county Tipperary, a district which includes a series of basins or troughs, separated into three or four portions by carboniferous limestone. The strata are sandstones and shales, with fire-clay and several valuable beds of stone-coal, of fair quality.

Coke from different qualities of coal was also exhibited, showing the great columnar masses into which it splits when made in large quantity.

We may also notice the various specimens of patent fuel, composed of coal screenings, made into solid bricks by the great pressure obtained by the hydraulic press, or mixed with pitch or coal-tar before being pressed. The coal-dust is cast in the form of bricks for convenience of stowage. In some cases, the excess of pitch is got rid of by heating the bricks to 600° in ovens. Although from the impurities of the small coal much ash and clinker is occasionally produced, yet it is a cheap and valuable fuel, turning to useful account refuse matters which were formerly either wasted, or embarrassed the producers.

Before dismissing the subject of coal, we must mention a very remarkable discovery in connexion therewith. Some years ago, a spring of mineral oil, similar to the springs of Persia and elsewhere, was discovered in a mine in Derbyshire. It yielded on distillation an oil which was found to be well adapted to the lubrication of machinery, and was in request at Manchester for the purpose. But the supply ceased. It occurred, however, to Mr. James Young, of Manchester, that this oil, being connected with the coal formation, might be produced artificially from coal. Accordingly, by distilling coal at a temperature much below that required for the production of gas, he succeeded in obtaining the oil in question, and a solid substance named *paraffine*, which will be noticed more fully when we come to speak of peat and its products. The coal, introduced at one end of a retort, is screwed out in the form of coke at the other end, while the liquid and solid products pass off by a separate opening. Important results may be expected from this discovery; for, in the enormous production of coke for railway locomotives, such valuable products as this oil and paraffine, which have hitherto been destroyed, may henceforth be preserved.

We come now to the limestones, as being next in geological position. They form a rich and valuable series, whether for building or for ornamental purposes. The display of marbles was striking, including as it did the black marbles of Kilkenny, the green and other delicate colours from Ireland, from the west of England, and Derbyshire. There, too, was the Magnesian limestone, used in the erection of the new palace at Westminster; blue lias limestone, consisting of carbonate of lime and alumina, and well adapted to the manufacture of hydraulic cements; the softer kinds of limestone; oolites and freestone; the oolitic or roe-stone, the ruins of a former creation of minute animals which the microscope reveals to us in Portland or Bath stone; the Caen limestone, whose fine texture adapts it so well to the purposes of building: in our climate, however, it does not bear exposure so well as in its native France, and hence our builders use it chiefly for interiors. Then we come to the grits, familiarly illustrated by coarse grindstones; a class lying between the old and new sandstone, the texture of which varies from that of granite to that of the softest sandstone. It is generally found that a firm and compact texture applies to that series of the grits which has borne for ages the accumulated pressure of other rocks. The softer sandstone, on the contrary, usually indicates a more recent period of formation. From the class of grits were formed the blocks for supporting the rails originally laid for the iron road between London and Liverpool; and it has been calculated that if these blocks were raised into a pyramid, it would exceed in dimensions that of the largest of the Pyramids of Egypt.

A large series of grindstones, exhibited by Mr. Meinig, included almost every kind used for manufacturing purposes in London. Until we saw this collection, we could not have supposed that so large a number of grindstones was in use in the arts. These gritstones are all varieties of sandstone; their abrading power depending on the degree of hardness of the stone, the size of the particles, and the siliceous character. The Bohemian grindstones exhibited are used by jewellers for polishing small works.

We must refer to our article STONE in the Cyclopædia for a methodical account of this part of our mineral wealth. In the Exhibition, many of the specimens of the rich collection of building stones were in the form of nicely squared 12-inch cubes, so that the weight of the cubic foot could be readily verified, and the physical qualities of the stone easily ascertained. The study of this valuable collection was greatly facilitated by the maps of the Ordnance Survey, geologically coloured, exhibited by Mr. Tennant. A glance at the coloured patches of this map sufficed to show the character of the buildings in the different districts so coloured. Thus it was easy to decide that brick buildings would prevail to the east of a line drawn from the Wash of Norfolk to Weymouth Bay; while to the north and west of that line brick would be less used than stone. This remark applies, of course, to ordinary buildings: public buildings would be of stone, brought from a distance; and in this respect the pious care of our ancestors, although with greatly restricted means of conveyance, far exceeded our own. They looked out for the most durable stone, without regard to cost or distance; we too often select that which may be easily and cheaply procured, without reference to its durability. For ordinary building purposes, however, the abundant stores of our eastern and southern counties suffice; namely, the Kentish rag, and the quarries of Corfe, in Dorset, of Reigate, and of Folkestone. Indeed, a large district, which is usually considered to be purely agricultural, furnishes valuable supplies of mineral wealth, such as white and grey chalk and lime, plastic clay, cement, terra cotta, stoneware pipes, patent hollow bricks, Kentish rag, fullers' earth, sand for glass-making, and common potters' sand.

The specimens of CLAYS exhibited were very complete, almost every kind of commercial clay being shown, both in its raw state, as dug out of the pit, and also in the semi-manufactured form adapted to the market. The China clay of Cornwall has been already noticed. Then there was fire clay, potters' clay, and the common marl clay used for making bricks and other coarse articles. The clays consist of silica, alumina, and water, in certain proportions. In the manufacture of earthenware goods, minutely divided silica is mixed with the clay, in order to prevent the vessels from the warping and cracking to which clay by itself is liable when exposed to the prolonged action of heat. At present the clay and the silica are mingled empirically, and it would seem to be the interest of the potter to throw a little more chemistry into his art, so that, by knowing the real composition of his clays, he could so proportion the silica as to produce a pottery-ware of as definite a character as if its ingredients had been combined by the hand of the chemist.

The BITUMINOUS SCHISTS or *shales*, combinations of bitumen and clay, furnish a variety of oleaginous and inflammable matters. Specimens of shale, known as *Kimmeridge coal*, obtained from the Isle of Purbeck, were exhibited, together with the volatile mineral oil, grease, asphaltum, and manure obtained from it. Bituminous schists have no peculiar geological limit: they appear to have resulted from the decomposition of large quantities of animal remains, as the peat-bogs of Ireland have from the decomposition of vegetable matter.

Some of the most interesting contributions from Ireland were PEAT and its products. About one-seventh part of Ireland is covered with peat or turf produced by the accumulation of marsh-plants and grasses, mixed occasionally with wood. The origin of peat-bogs has been explained by Mr. Nimmo. In cases where clay is spread over gravel, and the waters of floods or springs are prevented from escaping, muddy pools are formed, round the borders of which aquatic plants accumulate, and gradually creep in towards the deep centre. Mud having accumulated round their roots and stalks, a spongy semi-fluid mass is formed, well adapted to the growth of moss, which, together with spears of the *sphagnum*, now luxuriates: this absorbs a large quantity of water, and continues to shoot out new plants above, while the old are decaying and being compressed into a solid mass below. In this way the water is replaced by vegetable matter, and the marsh filled up; while the central or moister portion, growing more rapidly, gradually rises above the edges, until the whole surface has attained an elevation sufficient to discharge the surface-water, and flood the adjoining country. By some natural process of this kind peat-bogs were formed. In mountain districts moisture was supplied by clouds and mists, and one generation of vegetable matter flourished upon the ruins of its predecessor. But the

extent of these bogs depends greatly on the nature of the rock below. On quartz they are shallow and small; on a rock which by its decomposition yields a clayey coating, they are of great depth and extent. Summit bogs are distinguishable from those of lower levels by the total absence of large trees. As the plants which form turf are in different stages of decomposition, the aspect and constitution of the bog vary greatly. Near the surface it is light-coloured, spongy, and contains the vegetable matter but little altered; at some depth it is brown, denser, and in a more advanced state of decomposition; while at the base of the bogs, some of which are forty feet deep, the turf is black, nearly as dense as coal, and coming near coal in chemical composition. How to render peat valuable, is a problem of vast importance to Ireland: it is now in process of solution; and the facts already ascertained make the inquiry one of peculiar interest. Peat may become valuable, *first*, as a fuel; *secondly*, from its conversion into charcoal; and, *thirdly*, from the various products obtained from its destructive distillation. It is stated that 7 lbs. of properly prepared and dried peat will evaporate the same quantity of water as 6 lbs. of Newcastle coal; but while coal would cost the Irish labourer three times as much as it costs the Northumbrian cottager, the peat is at hand, and can be had almost for nothing. In order to obtain charcoal, blocks of peat are calcined in movable pyramidal furnaces. One exhibitor, Mr. Cobbold, prepares peat for fuel by mixing it with a large quantity of water, reducing it to an impalpable mud, and then, getting rid of the water by centrifugal force: a compact mass of considerable density is thus obtained, fit for use. The charcoal obtained from peat varies in character with that of the material which produces it; and when the peat is compressed previous to its carbonization, the resulting charcoal exceeds common wood charcoal in density. In stove drying, dense peat loses about one-third, and the light and porous kind one-half its weight: 4 tons of dried peat will give about 1 ton of charcoal. The deodorising and purifying qualities of this charcoal are high; and it is of great value in the manufacture of iron, on account of its being almost free from sulphur. The ultimate elements of peat are essentially those of wood and coal; viz. carbon, nitrogen, hydrogen, and oxygen. If, therefore, peat be distilled in close vessels, the resulting products must resemble those of a similar operation on coal or wood. Mr. Oxland exhibited the products obtained by the destructive distillation of Dartmoor peat in cast-iron retorts. The expense of this process, however, prevented its adoption in Ireland; but it occurred to Mr. Reece to employ a blast-furnace, similar to that used in the smelting of iron, only with the addition of an apparatus for collecting the products of combustion. In this way, peat has been made to yield ammonia, acetic acid, pyroxylic spirit, tar, naphtha, oils, and paraffine, all of great value in the useful arts. For example, the ammonia, which is fixed and separated by the addition of sulphuric acid, forming sulphate of ammonia, is employed in the preparation of carbonate and muriate of ammonia, of caustic ammonia, and in the manufacture of manures and fertilizing composts. The acetic acid, which is fixed and separated by the addition of lime, forming acetate of lime, is in constant demand as a source of acetic acid, and of various acetates largely consumed by the calico-printers. Pyroxylic spirit, or wood alcohol, which is separated by distillation, may be used with great effect in vapour-lamps and in the preparation of varnishes. Naphtha is also used in making varnishes, and for dissolving caoutchouc. The heavy and more fixed oils may be used as a cheap lamp-oil, and as a source of lamp-black; or, blended with other unctuous substances, they become well adapted for the lubrication of machinery. Paraffine is a crystalline substance, without taste, colour, or odour; at 112° it is a transparent, oily liquid, and at a higher temperature boils, and distils without change; its vapour burns with a white, sootless flame. Its sp. gr. is 0.870. It resists the action of acids, alkalies, chlorine, and potassium, and cannot be united by fusion with camphor, naphthaline, benzoin, or pitch. On account of this inertness as a chemical agent, or want of affinity, it derives its name from *parum affinis.* It unites, however, with stearine, cetine, bees'-wax, and colophony, and readily dissolves in oil of turpentine and in naphtha. By mixing paraffine with sperm and stearine, excellent candles may be formed. One exhibitor, Mr. Bagot, states that 100 tons of peat yield 10,000 gallons of liquor, containing ammonia, carbonic acid, acetic and pyroligneous acid, and pyroxylic spirit; 1,000 gallons of tar, containing paraffine, heavy oil, and light oil. The gaseous products are carbonic acid, oxygen, hydrogen, and nitrogen. The inflammable gas, which is economically

used by being passed under the steam boiler, is said to amount to 6,269 feet of inflammable gas. The 1,000 gallons of liquor afford 1 ton of sulphate of ammonia, sufficient acetic acid to produce 13 cwt. of grey acetate of lime, and 52 gallons of pyroxylic spirit. The tar yields 300 lbs. of paraffine, 200 gallons of naphtha, or light hydrocarbonaceous oil, and 100 gallons of heavy oils.

Intermediate between wood and coal is LIGNITE, a deep brown coloured substance, which, on being ignited, gives off much gaseous matter, burns brilliantly, and leaves a dense black charcoal. It has not been much used as a fuel, on account of its inferior value to coal as a source of heat. It is abundant in some parts of Ireland, especially on the shores of Lough Neagh. Beds of lignite occur at Bovey Tracey, in Devonshire, and at Bora, in Sutherlandshire; in various oolitic beds in Yorkshire similar mineral fuel exists.

The specimens of BRITISH ORES and METALLIC MINERALS exhibited were well calculated to give the student an exalted idea of the industrial wealth of this country; an idea which receives abundant confirmation from the fact that, independently of the cost of conveyance, the present annual value of the products of our mines is probably equal to 25,000,000 pounds sterling. But the money value of our raw materials expresses very inadequately their real moral, commercial, and industrial value. The mighty efforts which are carried on throughout the length and breadth of the land, in reducing the ores, working the metals into tools, useful articles, and products, to be again employed in giving value to other raw materials; in exciting and encouraging traffic with distant nations of the earth; in encouraging manufactures, and science as applied to manufactures, and hence promoting a taste for the study of nature, stimulating the manufacturer, the tradesman, and the artisan to acquire knowledge, and to secure it for his children; keeping up, in short, the energy of a great and free people: all these are advantages which would never have been realized or secured if our deposits of coal and iron-stone, our veins of copper and lead, had been nodules of auriferous quartz, or could, by the touch of an alchemist's wand, be transmuted into gold. If California should raise every year gold to the value of 25,000,000 pounds sterling, she would never by her gold alone rise to the proud position of a great manufacturing nation; for the gold of California is nearly as valuable in its raw as in its manufactured state; whereas, the value of the iron ore of this country depends on the science of the manufacturer and the skill of the workman. The value of an ounce of gold at the Bank of England is 3*l.* 17*s.* 9*d.*; the value of an ounce of steel chronometer balance-springs is 10 or 12 guineas.

The ores of IRON, LEAD, TIN, and COPPER, were not only illustrated by numerous specimens, but also by maps, working plans, and sections, models of mines or of strata, models of the machines employed, and in some cases the tools actually used in bringing the ores to a marketable condition. Iron being associated with coal in this country, the two were grouped near together. One of the chief advantages possessed by Great Britain in the manufacture of iron, arises from the number and variety of argillaceous and black-band iron-stones alternating with beds of coal in most of our coal-fields; so that the same localities, and often the same workings, furnish both the ore and the fuel required to smelt it. The limestone flux is also usually close at hand, together with the materials required in the construction of the blast furnace. Such a favourable conjunction of circumstances has under Providence contributed to the prosperity of this country. And here we must express our admiration of the splendid collection of iron ores made by Mr. S. H. Blackwell of Dudley, which for extent, variety, and all that gives worth to collections of this kind, was valuable indeed. The general iron making resources of the United Kingdom were illustrated by nearly 500 specimens, so arranged in lines on a large table as to point out at a glance the relative extent and importance of the districts which furnished them. First in order as in extent of production came South Wales, with various specimens of iron-stone from the eastern outcrop, from the northern outcrop, from the central anticlinal district, from the southern outcrop, and from the upper or red ash series. Then came specimens from North Wales, Shropshire, South Staffordshire, North Staffordshire, the northern district of Yorkshire, the southern district of the same county; the lias district being distinct from the great Yorkshire coal and iron field. All these ores are distinguished by local names, of which the

following, belonging to a portion of the Derbyshire ores, are specimens; and when the reader has read them, he will not, we think, be angry with us for having quoted so few:—*Chitters; Tufty Balls; Barren Beet; Grindstone Measure; Grinder's Wife; Big Balls; Pottom Flats; Brick Measure.* Northumberland, Cumberland, and Durham sent their brown hæmatites; Lancashire and West Cumberland also sent hæmatite; and the isolated district of the Forest of Dean also contributed its rich ores to this magnificent collection. Here the public had the rare opportunity of seeing the sources of the true *precious metal* of Britain; here the chemist and the mineralogist could study on a grand scale the characters of iron ores; and to the iron-master was afforded the facility, such as he never before enjoyed, of selecting such ores as would enable him to improve the character of the iron obtained from his own ores, for nearly every foundry can improve the make of its iron by mixing its own ores with those from adjoining or distant works. Thus in the refineries of Staffordshire may be found the pig-iron of South Wales mingling with the superior metal of Lancashire and the Forest of Dean.

Each of the iron districts contributed to the Exhibition something to illustrate its mode of working the ores; models of furnaces, and other interesting particulars. Thus the Ebbw Vale Company, near Abergavenny, sent samples of coal and iron-stone from their works in Wales, and also from the Coalbrook Dale iron-works in Shropshire; also maps showing the strata vertically of these mineral fields; a model of the mineral workings, taken both vertically and horizontally; a working model of the blast-furnaces; pieces of various pattern rails, bar-iron, angle-iron, &c. The reader may form some idea of the power of a large Welsh blast-furnace from the fact that it contains 150 tons of ignited material (iron-ore, coke, and limestone flux), and requires 20,000 cubic feet of air per minute. Indeed, an ordinary cold blast-furnace consumes as much air as is required for the respiration of 200,000 persons; and the *weight* of the air thrown into the furnace during the twenty-four hours by the blowing apparatus is often nine times the weight of the charge of ore, flux, and fuel. The Butterley Company contributed specimens of coal and ironstone, and of organic remains, in connexion with the Derbyshire coal-field, including analyses of the different coal strata. Also iron in its different stages of manufacture, including pig-iron, refined metal, puddled and merchant bar-iron. Messrs. William Bird & Co. made an interesting collection of Welsh pig-iron, cold-blast, bright, mottled, and white pig-iron, and refined metal; also anthracite pig-iron from Ystalyfera and Yniscedwyn iron-works; also Scotch pig-iron from the Gartsherrie, Calder, Govan and Forth Companies' iron-works; also various specimens of bar-iron, common, best and cable, fractured to show the fibre and tenacity, boiler and sheet-iron, a piece of chain, $\frac{5}{8}$ths inch diameter, proved to a strain of 19 tons; Staffordshire bars in 10-feet lengths, from $\frac{1}{2}$ inch to 6 inches diameter, and a bar of the *best best* iron upwards of 20 feet long, already alluded to [page lxxvi.]; railway bars, screws, nuts, spikes and boiler-rivets, tin-plate iron, iron-wire, boiler-plates, corrugated roofing-plates, &c. The Wingerworth Iron Company exhibited the two extremes of the iron factory—viz., a rough block of ore, and a bright polished drawing-room grate. One exhibitor had a bar of iron 63 feet long, in the form of a rail, rolled in one continuous length to exhibit the capability of the works for rolling. Another illustrated the tenacity of iron by exhibiting a book with iron leaves, 44 of which weighed $2\frac{1}{2}$ ounces, each leaf being $\frac{1}{700}$th inch thick. The Furness iron-ore (hæmatite) for mixing with inferior iron-ores was exhibited; as also pig-iron from hæmatite only. We cannot, however, in this brief notice, give an adequate idea of the extent and importance of the iron trade, as illustrated in the Great Exhibition. Referring, therefore, for more precise details on the subject to our article Iron, we conclude with a few general remarks.

Great Britain now produces annually upwards of 2,250,000 tons of iron, of which quantity South Wales furnishes 700,000 tons; south of Staffordshire, including Worcestershire, 600,000 tons; and Scotland 600,000 tons. The remainder is divided amongst the various smaller districts. There are about 450 iron furnaces in the United Kingdom, of which 7 per cent. may be out of blast. They consume annually about 10,000,000 tons of coal and 7,000,000 tons of iron-stone. A century ago our annual production was about 30,000 tons, or $\frac{1}{75}$th of the present rate. There is no doubt that the introduction of the hot blast has greatly

contributed to this result; but while that remarkable invention has rendered good service in one direction, it has done injury in another, by lowering the quality of the iron. The hot blast allows a considerable portion of the fuel to be used in the form of uncoked coal. Hence the ore in being reduced is exposed to the injurious influence of a larger proportion of sulphur than formerly, when the cold blast required the use of coke. The low quality of hot-blast iron is now so generally admitted that it is usual with engineers in making contracts with iron-masters to bargain for cold-blast iron. But whether with hot or cold blast, it is scarcely to be hoped that British iron will ever be able to compete in quality with the iron of Sweden, or even with that of Russia, Spain, or Austria. In Sweden, a rich ore and charcoal fuel tend to the fine grain and compact fibrous structure which are the usual characteristics of charcoal-iron. In Great Britain our iron-stones are poor, and our fuel sulphurous. These disadvantages, in conjunction with the hot blast, lead to the production of iron with a rough grain and a crystalline structure. The abundance of our raw material compared with the comparatively scanty supplies thereof in the countries we have named, will continue to us the supremacy of the iron-market; and it will be for our chemists to persevere in investigating this deeply interesting and important subject, to the end that the theoretical difficulties which still attend the iron manufacture may at length be solved.

From iron we pass to COPPER. Our article on this subject will convey a tolerably full account of the method of smelting copper ore as practised at Swansea. The specimens of ores and the results of processes exhibited at the Great Exhibition illustrated the methods adopted in other countries, which we shall endeavour briefly to describe. But first as to our own country. The copper ores contributed by Cornwall were numerous and complete, and some of the specimens of gigantic proportions. One specimen from Par Consols mine, at St. Blazey, weighed 1,500 lbs. The Redruth Local Committee sent specimens of yellow ore, ditto with fluor spar, grey and black ores, black in gosan,[1] &c.; together with illustrations of the various processes which the ore undergoes in preparation for the market, together with the methods for determining the percentage of pure copper. A valuable series of specimens illustrated the character assumed by the regulus of copper in its advancement from 33 to 78 per cent. There were also specimens of the stratum in which the ore is found. Mr. Taylor exhibited a model of the machinery and apparatus used for dressing the inferior copper ores, called *halvans*, but this will be better understood in our articles on MINES and METALLURGY, in connexion with other processes for the preparation of ores. The pumping machinery of the Cornish mines was exhibited, but there was no model which gave an adequate idea of the vast extent and importance of a Cornish mine, or of the busy scene of operations above ground for preparing the ores for the market or for the sample-heaps. Wales also contributed; but the collection disappointed expectation, for, considering that most of the copper ores of the world find their way to the Swansea valley, where the abundant supply of coal close to the water's edge gives facilities for unshipping and smelting the ores which the countries that raise them do not possess, a magnificent collection might have been formed at small expense. Specimens of crude ore, calcined ore, blistered and refined copper were, however, exhibited. Ireland, also, contributed, through the medium of the Dublin Society for the Encouragement of Native Industry. Scotland sent a portion of a large block of rich ore, weighing 6 cwt., from the Cally mines, Kirkcudbrightshire. The ore is a compound of the green and blue carbonates of copper, black, grey, and yellow copper, yielding from 25 to 30 per cent. of metallic copper.

It is sufficiently explained in our article COPPER, that the great bulk of the Cornish ore is the sulphuret of copper, combined with sulphuret of iron. This is sent from Cornwall, which has no coal, to Swansea, where coal is abundant, to be smelted. Here the ore is first roasted, by which much of the sulphuret of iron is converted into oxide, while the sulphuret of copper remains unaltered. The product of this operation is then strongly heated with siliceous sand, which combines with the oxide of iron in the form of a fusible slag, and separates from the heavier copper compound. When the iron is got rid of, by a repetition of these

(1) *Gosan* or *gossan* is a peroxide of iron, derived in most cases from the decomposition of copper pyrites, and usually found upon the *backs* of lodes: the gossans frequently contain silver. The clay slate in which copper ores, &c. occur is named *killas*.

processes, the sulphur is driven off by heat from the remaining sulphuret of copper, and an oxide of copper is formed. Lastly, the oxide is reduced by means of carbon and the curious operation of *poling*.

This method of smelting is liable to many serious objections, not the least of which is the entire loss of the sulphur, and the injurious action of its vapour upon the neighbourhood of the works. Probably, not less than 1,000 tons of sulphur are thus burnt to waste every week at Swansea, which, if converted into sulphuric acid, would yield upwards of 3,000 tons, and this, at the commercial price of one penny per pound, would be worth no less than 28,000 pounds sterling. Now an attempt has been made by Messrs. Bankart & Co. to save the sulphur in the following manner:—Copper pyrites reduced to a fine state of division is roasted at a moderate heat, whereby the sulphur of the ore becomes converted into sulphuric acid by combination with the oxygen of the air. The copper is also oxidized, and the acid combining with it produces a crude sulphate of copper, or blue vitriol. A second roasting with an addition of rich sulphur ore, converts all the metal into this salt. It is then dissolved in water, and the copper is precipitated in the metallic form by means of iron. The copper prepared in this way is remarkably pure. This process was illustrated by a complete set of specimens, of which the following is the instructive list. 1. Specimens of copper pyrites from the mines of the Cobre Association, in Cuba, averaging 24 per cent. of copper. 2. Dust or dressed ore from the poorer portions of the lode, averaging 14 per cent. copper. 3. Nos. 1 and 2 mixed and ground before roasting. 4. Ditto after the first roasting, whereby a portion of the sulphur and the copper are united in the form of sulphate of copper. 5. Ditto after being washed for the first time in boiling water. 6. Sulphate of copper in solution therefrom. 7. Roasted ore, No. 5, mixed with fresh ore, No. 3, for the second roasting. 8. Ditto after the second roasting, whereby not only the fresh ore is decomposed, as in No. 4, but portions of the sulphur in the freshly introduced ore mix with portions of the oxide of copper in the previously roasted ore. 9. Sulphate of copper produced by washing No. 8 in boiling water. 10. Metal produced from melting the washed ore No. 8. 11. Slag from ditto, which averaging only 0·15 copper, is thrown away. 12. Metal produced from roasting No. 10. 13. Slag from ditto melted up again with No. 8. 14. Blistered copper from No. 12. 15. Slag from ditto. 16. Copper precipitate produced from solutions Nos. 6 and 9, by passing them while hot over a piece of iron. This, with No. 14, is put into the refining furnace. 17 to 23. Copper in the various states through which it passes in the process of refining. 24, 25. Two ingots of copper (*best select*); the whole make of the same quality. The specimens Nos. 26 to 34 illustrated the various states through which the metal passes in the course of the processes Nos. 10, 12, 14, viz.:—

26. Coarse metal.	29. Pimpled regule.	32. Pimpled copper.
27. Blue metal.	30. Greasy regule.	33. Hollow copper.
28. White metal.	31. Spongy regule.	34. Set copper.

35. Crystals of sulphate of copper. 36. The liquids, Nos. 6 and 9, after having deposited their copper, and taken up iron in the form of sulphate of iron in its place. 37. Crystals of sulphate of iron from No. 36. 38, 39. Slag, No. 11 moulded in the form of bricks, which were used in the erection of the buildings at the copper-works. 40. Copper moss, the efflorescence from No. 28 when tapped out of the furnace.

Some copper produced by the above process, and adapted to the making of brass, was exhibited. We are not informed as to the expense of the process, compared with the usual method adopted at Swansea. This, of course, will determine its commercial success.

We must, also, here refer to Mr. Longmaid's process, in which copper pyrites, combined with common salt (chloride of sodium), is roasted at a moderate heat. A double decomposition is thus effected. Sulphate of soda is produced by the combination of the ore with oxygen, forming first sulphuric acid, which then unites with the soda produced by the oxidation of the sodium of the salt. The copper is also converted into a soluble sulphate; the iron is left in the state of peroxide, and the chlorine which is liberated is made to combine with lime, thereby forming bleaching powder. Specimens illustrating the various stages of this process were

exhibited. In this process, ores too poor to be smelted by the ordinary method can be made available, none of the products being thrown away, but all converted into marketable articles.

Most of the ores to which reference has been made in the above notice, and in our article Copper, are found in veins which traverse primitive formations. Such are copper pyrites ($Cu_2 S+Fe_2 S_3$) mixed in variable proportions with iron pyrites ($Fe S_2$). Far different in richness and value were many of the ores exhibited by our colonies: South Australia, for example, whose ores of copper are of the richest varieties. The celebrated Burra Burra mine exhibited beautiful specimens of the red oxide, the green carbonate, combinations of these two varieties, the red oxide, and the blue carbonate, native copper, malachite and fibrous malachite. Indeed, some of the specimens of malachite which are crushed and smelted for the sake of their copper, would, in Russia, be sliced into veneers, and employed in costly works of art. Specimens of the strata in which the minerals occur, and pictorial views of the mine, the smelting-house, and the township were also exhibited. These mines present a striking example of success in mining speculations. The mine was started in September 1845, with a capital of 12,320*l.*; and in the five years ending September 1850, not less than 56,428 tons of ore had been raised, varying in quality from 30 to 70 per cent. of copper, and of the value of 738,108*l.*

The lodes of copper thus worked are very different in character to the copper lodes of the primary rocks of this country. In the annotation to the list of specimens contributed by the Burra Burra mines, contained in the Illustrated Catalogue, are the following remarks:—"In a great basin formed in an amphitheatre of hills, an immense deposit of clay, the result of the decomposition of the clay slate, has taken place. This, under conditions which we are not enabled to determine, became also the reservoir for the reception of copper. In all probability it was first deposited in the pure metallic state,—a fine example of the electrotype process of nature. During this process, the so-called veins spread themselves through the soft clay in various directions, in precisely the same manner as we may, by carrying the terminal wires of a voltaic battery into a mass of clay saturated with sulphate of copper, form a curious arborescent mass. By the action of the oxygen contained in the water, this copper becomes oxidised by the slow process which gives rise to the very beautiful crystals of red oxide of copper, and from this state it passes into the blue and green carbonates, under the action of carbonic acid, the difference in the colour of the two arising from the quantity of water in combination."

In some of the secondary basins of Europe are cupreous deposits which are evidently due to the action of water upon the mineral vein. Waters which have traversed copper deposits are usually charged with sulphate of copper: if these waters filter through calcareous strata, or if they occupy cavities in calcareous rocks, a sulphate of lime is formed and carried off by the waters, while carbonate of copper is deposited. If this re-action take place under an elevation of temperature, oxide of copper, instead of carbonate, is deposited. But if the solution of sulphate of copper traverse strata containing organic matter, the sulphate may be reduced either to the state of sulphuret or to the metallic state. In this way may be explained the origin of those deposits of carbonate and oxide of copper, frequently met with near veins of copper pyrites, and also of the small crystals of sulphuret of copper disseminated through certain schistose rocks impregnated with bitumen, and containing organic remains. Such is the origin of the copper in the bituminous schist, which forms the bottom of an extensive secondary basin at Mansfeld, in the north of Germany. Specimens of this schist, which is full of the impressions of fishes, were exhibited by the combined mining works of Mansfeld (Prussian Saxony), together with a highly instructive series of specimens, illustrating the curious and interesting process of extracting the copper, which we now proceed to explain.

The copper schists or bituminous marl-slates (*mergelschiefer*) of Mansfeld contain a very variable percentage of copper, disseminated in the form of small crystals, and being strongly impregnated with bitumen, they thus contain a considerable portion of the fuel required for their roasting. They also contain variable proportions of lime, clay, iron, &c., and are sorted into varieties, according as the lime, the clay, or the iron prevails, the smelting being facilitated by observing certain proportions between them. The roasting is conducted in heaps

of 2,000 cwt., interstratified with brushwood and slates rich in bitumen. The heaps go on burning for 15 or 20 weeks, according to the weather. The bitumen is decomposed, the sulphur is converted into sulphurous acid, and the metals are partly oxidised. The calcareous ore loses one-tenth in bulk and one-eighth in weight by the roasting, and becomes friable in texture, and of a dirty yellow-grey colour. The post or charge for smelting may be made up in the following manner:—20 cwt. of ferruginous slate, 14 cwt. of calcareous slate, 6 cwt. of argillaceous slate, 3 cwt. of fluor spar, 3 cwt. of rich copper slags, and other refuse matter of former operations. The smelting is conducted with coke fuel, in a cupola about 18 feet high, or in a blast furnace, of which Fig. LII. is a vertical section through one of the blast pipes, tuyeres, or tweers, and Fig. LI. a front view, partly also in section. The sole and lower portion is of quartzose grit, the upper part of fire-brick. There are two tuyeres *t*, *t*, situated on the same face of the furnace, as in Fig. LIII. At the bottom of the hearth are two channels *o*, *o*, which are alternately opened to allow the fused products to flow into one or other of the cisterns C, C. The furnace is charged with the mineral and the fuel in alternate layers, and in the course of 15 hours 48 cwt. of the above mixture can be smelted, yielding from 4 to 5 cwt. of matte (crude copper or *kupferstein*) and a large body of slags. The matte and the slag are allowed to flow out into one of the basins by one of the channels *o*. When one cistern is full, the channel leading into it is stopped, and the other channel opened. The contents of the first cistern are then removed: the slags are moulded into large bricks, which are used for building purposes in the neighbourhood: the mattes are removed in the form of discs as they solidify on the surface. One cistern is thus emptied while the other is being filled.

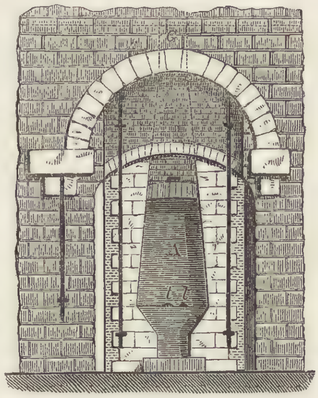


Fig LI.

Fig LII.

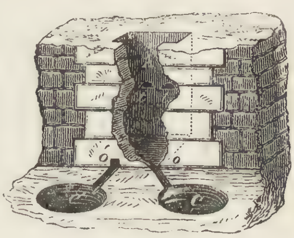


Fig. LIII.

The matte forms scarcely one-tenth of the weight of the charge; it consists of sulphuret of iron ($Fe S$) and sulphuret of copper (Cu_2S). The percentage of copper varies from 20 to 60, according to the nature of the mineral. When this matte contains only from 20 to 30 per cent. of copper, it is submitted to three successive roastings, and returned again to the furnace with the addition of a certain proportion of the scoria. For this purpose that scoria is selected which immediately covers the matte in the cisterns, which is of course richer than the surface scoria. In this way a new matte is obtained, presenting the same percentage of copper as that which proceeded from the smelting of the rich ores.

The rich mattes are subjected to six successive roastings in brick-walled kilns, Fig. LIV. furnished with openings *o* for assisting the draught. The entrances are closed by means of a fourth wall erected *dry* or without mortar, which prevents the heap from falling out, and can be easily removed. The matte roasted in the first stall is roasted again in No. 2, then in No. 3, and so on until it has passed through No. 6. During this roasting a considerable quantity of sulphate of copper is formed, which is removed by washing. For this purpose, after the third roasting, the matte is lixiviated in large wooden chests or vats placed one above the other, so that the solution from the first vat passes through the matte into the second; this in its turn passes through the matte of the third vat, and so on until the solution reaches the lower chest

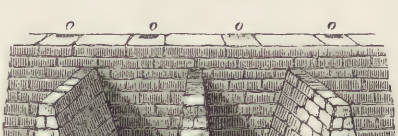


Fig. LIV.

in a nearly saturated condition, and by evaporation in leaden boilers it yields crystals of blue vitriol.

The roasting being completed, the matte is smelted in a furnace similar to Fig. LI., but of smaller dimensions. Scoriæ which will combine with the oxide of iron of the matte are added, and the product of this operation is *black copper*, a matte very rich in copper, and scoriæ. The matte is added to the richest of the second mattes of the preceding operation. The black copper is removed in the form of discs, which are produced by solidifying the upper layer in the cistern by pouring a little cold water upon it. The black copper contains about 95 per cent. of copper, 3 to 4 of iron, sulphur, and small quantities of silver and antimony.

The matte often contains a sufficient quantity of silver to render it worth extracting. This is done either by operating on the black copper or upon the last roasted matte. In treating black copper for silver the process of *eliquation* is adopted, and for the mattes that of *amalgamation*. The principle of eliquation is as follows:—if copper and lead be fused together, the two metals form an alloy; and if cast into a cake and cooled, the metals remain intimately mixed. Now if this solid alloy be gradually heated, or if the fused alloy be left to cool very slowly, the two metals separate; the lead retains all the silver which originally existed in the copper, and the copper remains in combination with only a small quantity of lead. The lead yields up its silver by cupellation, and the impure copper is submitted to the refinery. 3 parts black copper and 10 to 12 parts lead are melted together in a small furnace: argentiferous lead is preferred, or even litharge rich in silver. The alloy when properly fused is received into circular cast-iron moulds, which cool it quickly and give it the form of discs. These discs are heated on an eliquation hearth, formed of two plates of cast-iron, slightly inclined, with a small interval between them as in Fig. LVI. Below this is a chamber M formed by the masonry supporting the plates. The discs D are set up on edge on the cast-iron plates, and kept separate by means of wedges of wood; the side being then covered over with sheet-iron, as shown in Fig. LV., charcoal is poured between the discs and the wedges withdrawn. Wood is next put into the chamber M and the fire kindled, the draught being regulated by the flues *o*. As the temperature rises, the lead fuses, flows into a gutter at the bottom of M, and is received into a cistern or crucible *c*, Fig. LV. As this becomes filled, the lead is ladled into a cast-iron mould *e*, which gives it the form of lenticular cakes. The copper, alloyed with a certain quantity of lead, remains on the hearth in the form of semi-fused spongy masses. The lead separated by eliquation contains nearly the whole of the silver, and this is separated by cupellation; but it is probable that the Mansfeld exhibitors, taking a hint from the English department, will now adopt Mr. Pattinson's elegant process for desilvering lead.

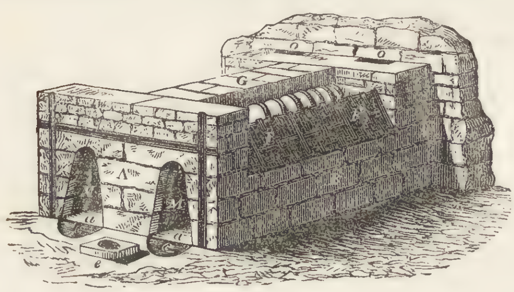


Fig. LV

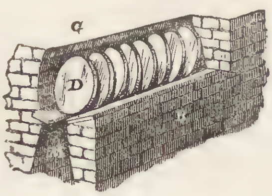


Fig. LVI.

The copper may be made to yield an additional quantity of argentiferous lead by submitting it to a higher temperature in a sweating furnace, shown in elevation, section, and plan, Figs. LVII., LVIII., LIX., the vertical section being made along the line C D of the plan, and the plan taken at the height A B of Fig. LVIII. The cupreous masses are piled up on the sole above the channels F, F, which are filled with wood. The door being closed, the wood is fired; the draught being regulated by the flues *o*, opening into the chimney H. A further portion of lead is separated by eliquation, which under the oxidising effect of the draught is converted into litharge, which falls to the bottom of the troughs F. A small portion of copper is also oxidised, and remains dissolved in the litharge. The product, therefore, on the sole consists of black copper deprived of nearly all its lead and silver, and argentiferous litharge rich also in copper; this is used in the cupel furnace, when the black copper is fused with lead in preparing the discs for eliquation.

The black copper, after the lead has been separated, is refined in a reverberatory furnace, of which Fig. LX. is a section taken along the line X Y of the plan Fig. LXI., which is taken along the line U V of the section. Wood is burnt on the hearth F, and the flame spreading over the sole A passes to the chimney C. The sole is covered with a mixture of clay and pounded charcoal: the charge is put in through D, the door of which is then closed. As soon as the metal is fused, the two tuyeres *t* are brought into action, and the nozzles being furnished with flattened jets, the blast is thus diffused over the whole surface of the bath. Under this influence the sulphur, the lead, and the iron are first oxidised: the slags are raked off by the door D. At the end of a certain time, the copper being freed from the other metals, red scoriæ are formed which are rich in suboxide of copper (Cu_2O). The operator judges of the progress of the refinery by plunging from time to time an iron rod into the metallic bath and withdrawing a die of copper, the behaviour of which under the hammer informs him as to its physical properties. The refining being complete, the metal is let out into the external cisterns B, B, and a little water thrown upon the surface: the effect of this is to solidify the external layer in each basin, which is then removed in the form of a thin porous bubbly disc of a fine red colour. By continually quenching the surface, these cakes or rondelles are removed, until the whole of the copper is disposed of. This copper is not malleable, its malleability being destroyed by the presence of a small quantity of suboxide of copper.

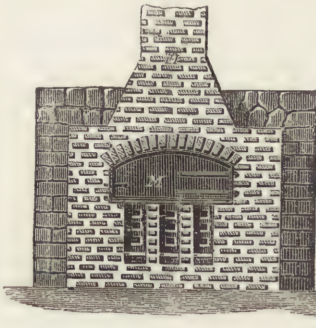


Fig. LVII.

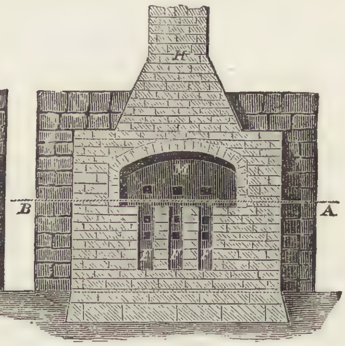


Fig. LVIII.

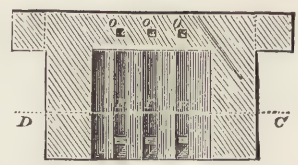


Fig. LIX.

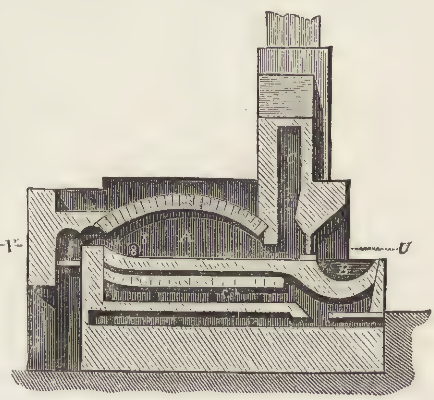


Fig. LX.

Black copper is frequently subjected to this process before being eliquated, in which case, however, the refining is not carried so far. The partially refined black copper is allowed to flow into cold water, which reduces it to a granulated form. These grains are fused with lead, in order to prepare the cakes for eliquation. In this way alloys of copper and lead are obtained of a more homogeneous character than when black copper in the form of discs is fused with lead. After eliquation and sweating, the copper is refined at a small hearth, to be described presently.

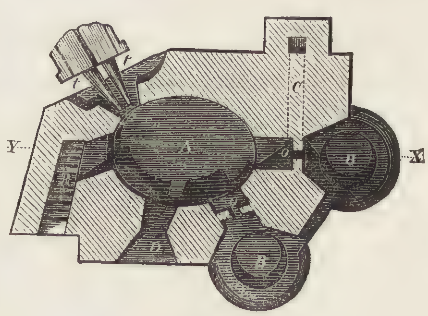


Fig. LXI.

When the black copper contains silver, the process of amalgamation is adopted; this will be described in the article SILVER in the Cyclopædia. When it contains no silver, the process of eliquation is omitted, and it is refined at a small hearth shown in section Fig. LXII., and in perspective Fig. LXIII. C is a hemispherical crucible of about 8 inches radius, lined with a puddle composed of 2 parts charcoal and 1 part clay. It is partly surrounded by a raised border, the open part of which has a door A. This border prevents the fuel from falling out. The crucible is fresh lined after every operation, and then dried during several hours by being filled with

ignited charcoal. Fresh charcoal is then heaped up, and bits of black copper are arranged opposite the tweer; the blast is then put on, and the copper being fused, a fresh quantity is added from time to time, the furnace being always kept full of charcoal. As the scoria accumulates, it is let off by the channel *i*. During the fusion, sulphurous acid is disengaged, with white vapours of oxide of antimony, if antimony be present in the black copper. The first scoriæ contain a good deal of oxide of iron; they are of a greenish colour: those which follow are of a deep red, very rich in oxide of copper. When a sufficient quantity of the black copper has been fused for one operation, the workman takes from time to time a die of copper upon the end of an iron rod, and when satisfied with its character, he stops the blast, throws a bucket of water upon the hearth, removes with his rabble the scoriæ floating on the surface, and when the surface is nicely cleaned, he throws upon it a little water for the purpose of solidifying the upper layer, which he removes in the form of a rosette. More water is added, and a second rosette removed, and so on until all the metal is disposed of. The process lasts about 2 hours: the loss is about 25 per cent. on the black copper, 75 per cent. of rose copper being formed.

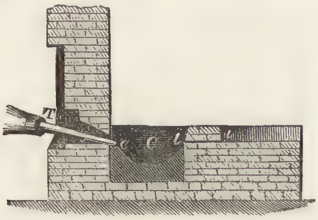


Fig. LXII.

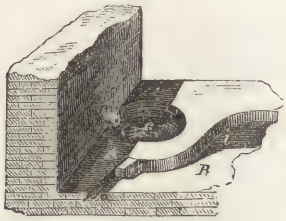


Fig. LXIII

This rose copper is wanting in malleability and in the fibrous character which distinguishes the copper of commerce. To impart these properties is a delicate operation, usually conducted at a distinct work, which is supplied with the rosettes from the copper-works. These rosettes are fused in a crucible, similar to Fig. LXII., and the surface is covered with small charcoal: at the end of some time, the whole of the suboxide of copper is reduced, and the metal has acquired its greatest degree of malleability. Unless the workman seizes the exact moment, the metal combines with a small portion of carbon and loses its malleability. The proper time for casting is discovered by operating on small dies taken out from time to time, and the purified metal is run out into ingot or other moulds.

The specimens in the Great Exhibition illustrating the Mansfeld processes, were as follows:—

Fig. LXIV.

1. Slabs of bituminous marl-slate. 2. The same with variegated copper ore and impressions of fishes. 3. *Sanderz.* 4. Calcined shale. 5. Slags. 6. Raw copper stone. 7. Powdered ditto. 8. The same after calcining. 9. Silver of cementation. 10. Fine silver. 11. Slags from the *kupferstein.* 12. *Dünnstein* or thin copper stone, a sulphuret of copper and iron produced in the original smeltings. 13. Black or raw copper. 14. *Mansfelder gahr-kupfer* or refined copper. 15. Fine copper in ingots from 35 to 40lbs. weight; in bars 3 feet long, from 18 to 20lbs. weight. Also a square proof rod of copper, Fig. LXIV., beaten out at one end to show its malleability, and broken at the other to show the fibrous texture. A similar rod was also shown twisted into a tolerably close spiral.

Several rosettes of copper were exhibited by Russia, Sweden and Norway, and Spain. They were obtained by processes resembling, in some respects, those just described.

The specimens of native copper exhibited, were highly interesting and of great importance. A portion of a slab of copper found in the serpentine formation in Cornwall, was, when taken out, 30 feet in length, and its produce 96 per cent. The fissures in the serpentine rocks are filled in with various mineral substances, and occasionally a slab of native copper is found. In the United States collection, was a mass of native copper weighing 2,544lbs., from the North West Mine, Lake Superior.[1] A portion of this copper rolled out into a ribbon was not to be distinguished from pure copper. Many fine specimens were also exhibited from the Canadian shores of this lake. Mr. Logan, the director of the geological survey of Canada, thus describes the copper region of Canada:—

(1) This specimen formed part of the noble collection of United States minerals exhibited by Dr. Feuchtwanger, of New York. The collection was sold in London by auction, 18th October, 1851, when the above mass of copper realized 95*l*.

Belonging to a formation which is interposed between the lower Silurian rocks and the gneiss, an extensive copper region occurs in Canada. From the boundary of the province at Pigeon River, it ranges along the northern and eastern shores of Lake Superior, and the north shore of Lake Huron for a distance exceeding 400 miles. On Spar Island, in Prince's Location, a 4½-feet lode, holding vitreous copper in a gangue of calc-spar, barytes and amethystine quartz, cuts clay slates overlaid by green-stone trap, and yields on an average about 7 per cent of pure metal. On several islands of the Archipelago, which separates Neepigon Bay from the main body of Lake Superior, native copper occurs; and on St. Ignace Island, which is the largest of them, a vein of about 2 feet running with the stratification has been traced the whole length of the island. Fine specimens of native copper were obtained by sinking a shaft on this lode. Many of these specimens were beautifully crystallized; vitreous copper often accompanying the native. Native copper also occurs in Michipicoten Island; and the formation of this island, and of the islands of the Neepigon archipelago, consisting of greenstone and amygdaloidal trap, interstratified with sandstone and conglomerate, is in every respect the same as that of the Cliff, and other mines on the south of the lake, celebrated for the large masses of native copper which they have produced. At Mica Bay and Mamainse, the vitreous and yellow sulphurets, as well as the native copper, have been obtained. On the north shore of Lake Huron, the prevailing description of copper ore is yellow sulphuret, and the veinstone is usually quartz. The prevailing rocks of the country are greenstone trap, slate and quartz rock, interstratified with one another; and it is in places where the lodes cut the greenstone that they become most productive, while they are least so in quartz rock. Although lodes exist in several parts, it is only those of the Bruce mines that have been worked to any extent. In July 1848, on a close examination of the lodes by the geological survey, a length of 300 fathoms, with a depth of 10 fathoms and a breadth of 4 feet, gave an average of 6½ per cent. of available pure metal; and 1,475 tons of vein stuff on the surface, as it had come from the lode, then sampled, gave 8 per cent. The ore has sometimes been dressed to 23 per cent. and generally to between 15 and 20 per cent., at which produce several hundreds of tons have been sent to Boston; and 200 tons of 15¾ per cent., intended for Swansea, are now in Montreal. Smelting works have been established at the Bruce mines, and a cargo of tough cake-copper shipped to the United States; one of these cakes has been sent to the Exhibition as a sample. The furnaces are of the reverberatory description, and the fuel used is bituminous coal, obtained at Cleveland on Lake Erie. Wood abounds in the vicinity of the mines. The yellow sulphuret of copper occurs at the Wallace-mine location, near White Fish River, to the eastward of the Bruce mines, in thin strings supposed to be leaders to some main lode not yet discovered; and these are worthy of notice, from the fact that sulphuret of nickel accompanies the copper, disseminated in patches, and the nickeliferous part of the ore, when freed from earthy impurities, is found to contain 13 per cent of pure nickel; traces of cobalt accompanying the nickel. Copper ore occurs in the metamorphic rocks of the Eastern townships in Upton, associated with silver, and in Ascott with silver and gold; but the quantity does not yet appear in any instance to hold out much prospect of a profit.

Tin was properly associated with copper in the Exhibition, and the trade of ancient Cornubia was strikingly illustrated by a rude smelted block found in Ladock near Truro, and supposed to have been smelted when the Phœnicians and people of the Mediterranean obtained from Cornwall the tin used in fabricating the bronze for the statues and works of art which we now so fondly cherish in our museums. How strange that this rude block should have been prepared by our skin-clad ancestors for the masters of the world: that they should have passed away, and that the small island, which they despised and pitied, should be mistress of an empire whose shores are washed by every sea! The Truro Local Committee had a number of important specimens illustrative of tin: they were contributed from various Cornish mines, and exhibited the ore in its various stages until it leaves the miner's hands as black grain tin: also a block of very pure white tin.

Oxide of tin is found in the beds of streams and in deposits at the base of the primary rocks: hence it is called *stream-tin*, and the facility with which it was obtained was doubtless the origin of the ancient British trade. Tin is also found in the lode as peroxide, cupreous sulphuret of tin or tin pyrites. The dressing of tin ores is rather a complicated process, (for which we must refer to our article Tin,) by which they are prepared for the smelter, who has only to carry them twice through the furnace: by the first smelting they are brought into the metallic state, and by the second the metal is sufficiently purified. Mr. Bolitho exhibited a model of a reverberatory tin smelting furnace, standing in the centre of a revolving table 51 inches in diameter, surrounded by specimens of various ores prepared for smelting, as well as products from the smelting works. The revenue of the Duchy of Cornwall being derived in great measure from duties on tin, the trade is to some extent restricted; the law formerly required that all the tin ore raised within the Duchy should be smelted therein: it even prescribed the localities for smelting, and the form in which the metal should be cast, viz. in blocks of about 3 cwt. each, whence the term *block-tin*. The stannary laws, however, were simplified in the reign of William IV. and also in the first year of the present reign.

Mr. Oxland exhibited an instructive series of specimens illustrative of an improved process for dressing those tin ores which contain wolfram, (the tungstate of iron and manganese.) The sp. gr. of wolfram being from 7.1 to 7.5, while that of the black tin of the mines or the pure native oxide of tin is only from 6.3 to 7, it was not possible to separate the wolfram from the tin oxide by the usual mechanical process of washing in a stream of water. The chemical process was therefore adopted, which these specimens were intended to illustrate. No. 1, *Tin-witts:* the ore obtained from the stamping floors is washed in a stream of water to separate the lighter earthy particles: the clean *witts* contain native oxide of tin, black or rosin-tin, and wolfram, with iron and arsenical pyrites, generally containing some copper. In the course of washing, the witts are separated into different parcels according to the size of the particles, and are known as *jigged*, marked A; *flucan* B; *smalls* or *smales* C; *slime* D; *roughs* or *rows* E. The witts are calcined until all the sulphur and arsenic is evolved. The residue (No. 2) contains black tin, or native tin oxide, peroxide of iron, wolfram, some sulphate of copper, and a small quantity of earthy matter. By a series of washings the peroxide of iron, sulphate of copper, and earthy matters, are removed, and the product (No. 3) consists of oxide of tin with most of the wolfram. The proportion of wolfram having been ascertained by analysis, a quantity of sulphate of soda or salt cake is mixed with the ore, sufficient to supply a slight excess of the equivalent of soda for the quantity of tungstic acid present. A quantity of coal dust or charcoal is mixed with the sulphate of soda, to afford carbon or carburetted hydrogen for the decomposition of the sulphuric acid, and the conversion of sulphate of soda into sulphide of sodium. The mixture is heated on the bed of a furnace, first with a smoky or reducing flame, and after the charge has been at a red heat for some time, an oxidating flame is required to complete the process. Thus the sulphate of soda is first converted into sulphide of sodium; then the tungstic acid of the wolfram combines with the soda, producing tungstite of soda, setting the sulphur free as sulphurous acid, and leaving the iron in the condition of a light finely divided peroxide. The product (No. 4) is removed while hot into tanks containing water, which quickly dissolves the tungstate of soda. The solution is run off into receivers, and the residue removed to the floors, where by a series of washings the peroxide of iron is removed, and the native oxide of tin (No. 5) obtained pure and ready for the smelting house. By this operation the value of the ore is raised from 42*l.* per ton to 56*l.* The tungstate of soda (No. 6) is obtained in the crystalline form by evaporating the solution in which it was separated from the tin. It is proposed to use this as a substitute for stannate of soda as a mordant for dyeing. Tungstic acid (No. 7) may be used for the same purpose, or for the manufacture of tungstate of the tungstous oxide with soda, a compound much resembling gold. The tungstate of lead (No. 8) and tungstate of lime (No. 9), are good white pigments, (manufactured from the tungstate of soda,) from which was obtained the metallic tungsten (No. 10), and sulphuret of tungsten (No. 11). The former is for use in the manufacture of metallic alloys: the latter has been proposed as a substitute for black-lead.

Zinc was not so well illustrated in the British department as some of the other metals. There were very few specimens of ore, and the peculiar method of smelting was not shown. The limestone ranges of Derby, Flint, and Somerset, are the principal localities of zinc in the United Kingdom. It occurs in the form of carbonate of the oxide, or *calamine*, and of sulphuret. The latter, also called *Blende* or *Black Jack*, is important as a source of the pure metal, which is obtained by roasting the ore, and exposing it to heat in proper distillatory vessels mixed with charcoal, and completely protected from the air. When exposed to air at a high temperature, zinc takes fire and burns with a bluish-white flame, and is converted into a white oxide, which, from its innocuous qualities, is now taking the place of white-lead in the manufacture of white paint. Numerous specimens of rolled or sheet zinc were exhibited; and also various articles made therewith, such as pails and milk-pans, perforated zinc for the purposes of ventilation, and zinc distorted into the many frightful forms with which the smoke-doctor haunts the sky-line of our houses. But the grand display of zinc was in the foreign departments. The Vieille Montagne Company of Liege exhibited specimens of the Belgium calamine in the piece, and washed; the ore calcined and ground, and the ore and charcoal mixed

for the furnaces. Also raw zinc, sheet zinc, sheathing, household utensils, tin-smiths' work, bars for ships' nails, drawn zinc for nails of all kinds, grey oxide for paint, and cement for boilers. This company deals so extensively in zinc, and introduces the metal so cheaply into Great Britain, as to render the working of our native blende unprofitable. This zinc is very pure, containing only a little iron, and some traces of lead and sulphur. The United States exhibited, in the eastern main avenue, a block of the red oxide of zinc, weighing 16,400 lbs., from the Sterling Hill Zinc Mine in New Jersey, about fifty miles from New York. The zinc ore occurs in white crystalline or altered limestone, in a regularly formed vein or stratum, with an inclination or dip of about 80° and a thickness of several feet at the surface or outcrop. The ore is very rich and pure : millions of tons of it are in sight above water-level, and can be got out by quarrying. The massive sample exhibited was got out at a single blast from near the surface on the brow of the range of hills in which the vein outcrops. Under ordinary circumstances, the produce of the mine is conveyed to New York by canal ; but before it was decided to send this specimen to the Exhibition, the canal was frozen for the winter, and it is said to have cost 200*l.* for getting it conveyed by land. No means of moving a mass of such immense weight being at hand at the mines, a truck of the largest size was sent for the purpose from New York. The first attempt failed from want of proper apparatus, and the truck returned. A second truck, fitted out completely for the service, was then despatched. The task was one of great difficulty, for within twenty miles from the mines, three high ranges of mountains were to be crossed. It was mid-winter : the roads were bad, and in some places quite precipitous. Heavy teams of horses and oxen were required to draw the truck up the mountains, and in descending it had to be held back by strong block-and-tackle rigging fastened to the trees on the roadside. The ore was then conveyed from Dovor to New York, a distance of forty miles, by railway. It was then conveyed on a truck to the Navy Yard at Brooklyn, where it was shipped on board the United States Frigate, St. Lawrence. Having been landed at Southampton, it was conveyed to London by the railway company without charge.

The recent application of zinc in place of the more classic but costlier material bronze, received abundant illustration in the Exhibition. Zinc can be fused at a comparatively low temperature, it liquefies completely, and therefore fills up the smallest lines of the mould, so that the work requires little subsequent chasing; it is durable in the open air, and its cost is only about a sixth or an eighth that of bronze. These are undoubted advantages; but the colour is so repulsive, so very inartistic, that our pleasure in studying some of the works of art cast in zinc was greatly interfered with. We would only refer to the colossal statue of Her Majesty Queen Victoria, cast by M. Paillard, of Paris, and exhibited by the Vieille Montagne joint-stock company, and inquire whether the application of zinc to such purposes is defensible? The objection as to the colour has been, however, to a certain extent overcome by M. Geiss, of Berlin, who has succeeded in imparting to the zinc by electro-chemical action a metallic surface resembling Florentine bronze. The colossal group of "the Amazon on horseback attacked by a tiger," after M. Kiss[1] of Berlin, was a happy illustration of zinc casting, and of the new method of bronzing. Still we are not satisfied, for the objection is only removed by creating a sham: by making a work of high art pretend to be in bronze when it really is in zinc. If the natural colour of the inferior metal be unfit for works of art, it ought not to be used; if fit, it ought not to be disguised. The exquisite taste of the ancients led them to select bronze as a beautiful, appropriate and durable material ; but they would have revolted from the idea of making a base material look like one of higher value. Modern art will never be in a fair position to attain excellence until the great principle that "honesty is the best policy" be admitted into the application of her raw materials.

Lead was admirably represented. The ores of this important metal occur in considerable abundance in Flintshire and Denbighshire, in Scotland, in Durham, Cumberland and Yorkshire, in Derbyshire, Shropshire, Devon and Cornwall; also in Ireland. The principal ores are *galena* (from *galeo*, to shine) or sulphuret of lead; *specular galena*, forming the resplendent

(1) The original was cast in bronze in 1839, by a number of amateurs, and presented to the King of Prussia. It was placed by his Majesty's command in front of the Royal Museum, Berlin.

slickensides of Derbyshire—thin seams which split asunder with a kind of explosion when scratched by the miner's pick; *argentiferous galena*—containing variable proportions of silver—*seleniuret of lead*—*native minium* or *red lead*—*carbonate* or *white lead*—also the *sulphate*, *phosphate*, *muriate*, *arseniate*, *chromate*, *tungstate*, *molybdate*, &c. of lead. Specimens of these minerals, many of them of great size and beauty, were exhibited. A peculiar ore, the arsenio-phosphate, was sent from Cumberland: it appears to be an arseniate of lead in which the arsenic is partially replaced by phosphorus; it has been used in the manufacture of glass, for the purpose of improving its transparency. We must also specially notice a specimen of silver lead ore from North Wales, weighing 350lbs., containing 16cwt. 3qrs. 10lbs. of lead per ton, and $82\frac{2}{5}$ ounces of silver per ton of lead.

Mr. Sopwith exhibited an admirably selected and arranged series of specimens, sections and models illustrative of the lead-mining district of Allenheads in Northumberland, the property of W. B. Beaumont, Esq., and the processes carried on in working the ores; also a plan and section of a considerable tract of mining-ground in the manor of Alston Moor in Cumberland. The specimens of the argentiferous lead ores and the associated minerals showed the various stages of progress from the mine through the several departments of washing and smelting, until ready for the market in the form of a cake of silver and a pig of lead. The extent of Mr. Beaumont's mines in the dales of East and West Allen, and of others at the western extremity of Durham, may be judged of from the fact that they furnish about one fourth of the quantity raised in England, about one sixth of the produce of Great Britain, and about one tenth of that of the whole of Europe, including the British Isles. The sectional drawing of the Allenheads exhibited was $16\frac{1}{4}$ feet long on the scale of 100 feet to an inch, the lengths and heights being projected to the same scale or proportion, so that a true miniature profile of the country was given, as well as a correct reduction of the relative size of the various rocks. Nearly four miles were thus shown. "In a thickness of about 2,000 feet of the alternating beds of sandstone, clay, and limestone which form the strata of the mining districts of Allendale, Alston, and Weardale, there is one single stratum of limestone called the 'great limestone,' the veins of which have produced nearly, if not quite as much ore as all the other strata put together. This stratum is delineated on the section, and may be observed lying at a depth of about 850 feet below the summit of Kilhope Law.[1] Somewhat exceeding two miles eastward of this, at Allenheads, the top of the great limestone is 230 feet from the top of a shaft called Gin-hill shaft. Its thickness, which is tolerably uniform over several hundred square miles of country, is about 60 feet, and it is from this stratum of limestone that nearly all the specimens in this collection have been obtained."

This great lead district was further illustrated by models showing the actual forms of the strata, and so made up as to admit of being dissected and put together again. Thus, No. 1 represented a square mass of part of the carboniferous or mountain limestone strata, showing the little and great limestone, and on removing the upper portion of the model the result of the extensive denudation[2] was shown which is so conspicuous throughout the mining dales of the north of England. The second model represented the principal seams or beds of coal in the district east of the lead-mines of the north of England, and situated, as regards geological sequence, above the mountain limestone strata. Other models represented interesting points connected with the arrangement, dislocation, &c. of the strata, and the geological and mining conditions of the district. The remainder of the collection was arranged with a view to exhibit, *first*, the productions upon which the industry of the lead-miner has to be exercised; *secondly*, the processes by which he renders these productions fit for use, and *thirdly*, the results of his labours. The detail of these important subjects must be reserved for our article LEAD; but there are one or two points which may be more appropriately noticed here than in the body of the Cyclopædia. Respecting the *first* of the above subdivisions, it had been proposed to exhibit in a separate case labelled specimens of the principal rocks, ores, and spars of Allendale and Alston: the interesting reason for abandoning this plan, is thus stated by Mr. Sopwith:—"A number of agents and other

(1) Kilhope *Head* is the point where the three countries of Northumberland, Durham and Cumberland meet. Not far from this is Kilhope *Law*, the highest point of land in Durham: it is 2,206 feet above the level of the sea.

(2) The carrying away of a portion of overlying materials by the action of water.

parties interested in lead-mining, and chiefly residng in Alston Moor, was anxious to send a collection of minerals obtained from lead-mines to the Exhibition, and a working miner, Mr. Isaac Robinson, who was one of the parties, was anxious to fit up this case in a manner corresponding to some small collections which he had cemented together, and which had been much admired. As such a collection formed, in point of fact, the essential feature of the first division which had been contemplated, being specimens of the minerals associated with lead, it was considered at a meeting of the parties concerned that it should be fitted up as proposed by Mr. Isaac Robinson, under the general superintendence and direction of the exhibitor [Mr. Sopwith] and others. This was accordingly done, and the case contains upwards of 2,000 specimens fitted together, not as a representation of any particular cavern, but grouped so as to present to view an example of almost every mineral substance usually found in immediate connexion with lead ores. Some of the examples are interesting as ornamental spars. But spars are not alone useful as ornaments; they are partly used in the arts, and they also afford instructive indications in tracing the course of mineral veins. The whole of this case was cemented together by Mr. Isaac Robinson, during the intervals of his ordinary hours of work." 170 varieties including 2,000 specimens were thus put together, and a list thereof is inserted in the illustrated catalogue containing the name of the mineral, its locality, and the name of the mining agent or workman who contributed it.

The specimens illustrating the various stages of progress of the ore from the mine to the market, were arranged in five cases, each containing six boxes of one square foot each; 15 of these contained specimens of lead-mining from the excavation of the ore in the mine, showing the various stages of progress, until ready to send to the smelt-mill; the other 15 boxes contained specimens of the ore as prepared for smelting, and its various stages of progress, until manufactured into lead and the silver separated. The *bouse* or lead ore (No. 2.) showed the "curiously polished surface [*slickensides*] which is a frequent characteristic of veins, and which would appear at first sight to have been very carefully polished by artificial means, many of the surfaces being sufficiently clear to reflect the images of objects in a tolerably definite form." The picking, washing, and sizing of the ores; the roasting and smelting, were illustrated by various specimens; slags were also shown, and crystals of selected and common lead as formed in the process of separating or desilvering the ore by Mr. H. L. Pattinson's method, first brought into operation at Mr. Beaumont's smelt-mills. The old method of separating the silver was by *cupellation;* the roasted sulphuret was exposed to the action of heat and air in shallow earthen dishes; the lead became oxidized and converted into litharge, while the silver, resisting the oxidizing influence, was left pure. [See Assaying.] The new method is founded on the property which fused lead has of becoming solid or crystallizing at a lower temperature than silver, so that if a quantity of argentiferous galena be reduced to the liquid state and then allowed to cool, solid crystals of nearly pure lead will first be formed; these can be separated by means of an iron strainer, and in proportion as this is done, the liquid mass left behind becomes richer and richer in silver. The process is conducted in hemispherical cast-iron pans, each holding about 3 tons of metal, and heated by a fire below. The process is repeated for 3 or 4 times for each charge; and the rich silver liquid is finally purified from lead by cupellation. In this way ores containing only 3 ounces of silver to the ton can be profitably worked for the sake of the silver, the lead, of course, not being commercially deteriorated thereby; by the old method of cupellation, ores containing less than 20 oz. of silver per ton scarcely paid the expense of extracting the silver.[1] A cake of pure silver, weighing 8,000 ounces, was exhibited; it was produced from lead raised in Mr. Beaumont's mines. Various specimens of litharge were also shown, also specimens of *fume* or deposit of the smoke in the long flues connected with the smelt-mills; also thin films of oxide from the surface of melted lead, showing iridescent hues of great intensity and beauty; pig moulds and pigs of lead; the pigs weighed 1½ cwt. each, and it was stated that the number usually manufactured at these mines in a year would, if laid in one continuous line, extend upwards of 70 miles in length.

(1) Mr. Pattinson exhibited specimens and a large drawing to illustrate his process. The process was also admirably illustrated by the Duke of Buccleuch's specimens, No. 509.

Again expressing our admiration at Mr. Sopwith's extensive and admirably arranged collection, we must pass on and notice briefly the improved furnaces and pots employed on the Duke of Buccleuch's mines at the Wanloch lead-mills in Dumfriesshire, for separating silver from the rich lead ore of the district. The smoke arising from the furnaces of the large smelting-works of this class contains much poisonous matter, and a considerable quantity of lead. The models exhibited showed the method of condensing the smoke into a *fume* or deposit containing about 33 per cent. of pure lead, and nearly five ounces of silver per ton. For the details we must refer to our article LEAD. The results of this arrangement are stated to be most apparent and beneficial to the surrounding district. "Formerly the noxious fumes passing from the shafts of the furnaces poisoned the neighbourhood; the heather was burnt up, vegetation destroyed, and no animal could graze or bird feed near the spot. Now the heather is seen in luxuriance close around the establishment, the sheep graze within a stone's throw of the chimney's base, and game on all sides take shelter."

PLUMBAGO, GRAPHITE, or BLACK-LEAD, one of the numerous forms in which carbon occurs, and of considerable importance in the fine arts and the useful arts, was admirably illustrated by Mr. Brockedon's contributions. These included samples from the mines of Borrowdale in Cumberland, such as were formerly found, and admitted of being cut into slices, and used in the natural state: the supply of this kind appears to have ceased, the plumbago now supplied from Cumberland being too gritty to be used without purification. The Ceylon plumbago exhibited was crystalline and fibrous, but too fragile for use in cedar; it is, however, the purest plumbago known, containing 98.55 pure carbon. There were two samples from Davis's Straits and Greenland, and one from California. Samples from Spain and Bohemia (the last called Mexican,) illustrated the varieties, which being hardened by fusion with sulphur, are used in the manufacture of common pencils. A fine pencil cannot be produced from any of these varieties except the Cumberland, and as the failure in the supply precludes the old method of slicing, it occurred to Mr. Brockedon some years ago, to reduce this plumbago to a very fine powder, then to exhaust the interstitial air, and subject this powder to intense pressure; by which means adherent masses were formed, as dense and as applicable to the same purposes as the original plumbago. Specimens of the Cumberland plumbago in powder, purified from grit, and in fine powder ready for condensing, were shown. A quantity of this powder weighing seven ounces, is solidified in two blows with a force of 5,000 tons; slices are cut from the block thus formed, and the edge of a slice, being inserted in channels in the cedar, is cut off, and the process repeated until the groove is filled. This plumbago is also cut into square threads, which are rounded, and cut to the proper lengths for ever-pointed pencils. The cedar used in making pencils is imported into London and Liverpool chiefly from South America. The inferior plumbago is used in the manufacture of crucibles, or chemical furnaces; the powder is used in anti-attrition applications; but the black-lead sold for domestic purposes is often adulterated with lamp-black.

PLATINUM and its associated metals, PALLADIUM, IRIDIUM, and RHODIUM were illustrated by Messrs. Johnson and Matthey. These metals are obtained from the Uralian Mountains, and from the alluvial deposits of Brazil and other parts of South America. From its great infusibility and its power of resisting the action of almost all acids at a boiling or even a red heat, platinum, the heaviest substance that has ever been weighed, is of great importance in many of the arts and in the laboratory. Crucibles, capsules, &c., oxide and spongy platinum, were exhibited; also an ingot of *palladium*, a steel-like silvery metal, hard and not liable to tarnish: hence its use to instrument-makers for the fine graduations of those instruments which are to be exposed to the atmosphere: a cup of palladium soldered with fine gold was also shown: also the alloy of silver and palladium used by dentists; the oxide of palladium and its salts. *Iridium*, so called from the *iris* or rainbow colours, which it exhibits in its different states, was represented by a vase. The native alloy, as used for nibs of pens, was also shown. *Rhodium*, so named from the *rose* colour (ῥόδον, a rose) of one of its compounds, was represented by a vase; its sodo-chloride, oxide and phosphuret. URANIUM was also illustrated in this collection: this metal is found in Cornwall in *pechblende*, a very impure oxide of uranium, and also in France in the varieties of uranitic mica. The addition of the peroxide

to glass imparts to it a peculiar and beautiful golden green, of an opalline lustre, a specimen of which was exhibited in the form of a glass vessel. The green oxide has been used in the Berlin porcelain manufactory to produce a black colour. Uranium is very scarce, or it might probably be applied with advantage as a source of pigments.

Antimony was well represented in Mr. Hallett's contributions; among which were the sulphuret ore, from Sarawak, Borneo, Leghorn, Tuscany, and the oxide from Algeria. The refined sulphuret, or the *crude antimony* of commerce, used in medicine, dyeing, pyrotechny, and chemistry, was shown. Also metallic antimony, or *regulus*, named *best bowl regulus.* Also metallic antimony, more highly refined, exhibiting its natural crystallized, or fern-like, surfaces, and its fracture, known in commerce as *best French quality regulus.* The use of antimony is chiefly to harden other soft and ductile metals: it is used with lead and tin, for printing-types; with copper and tin, and sometimes lead, for Britannia or Queen's metal, pewter wares, &c. Melted with tin, it has been lately used as an anti-friction alloy, for railway axles, and other bearings, in metallic rings or collars for machinery, &c.; and it is stated, that as this alloy does not become so much heated by friction as some of the harder metals, less grease is required.

The ores of Cobalt and Nickel were of great interest; the former being the basis of the blue colour in our earthenware, &c.; and the latter, an essential ingredient in various metallic alloys, such as *albata, German silver,* &c. The latter term indicates the source of much of our nickel; but Norway and the Netherlands supply a portion, as well as Germany. The two metals are usually associated together in the same ore. A specimen of ore found near Keswick, in Cumberland, was exhibited by Captain Barrett, containing from 2 to 3 per cent. of cobalt, but no nickel; an unusual circumstance, as even in meteoric stones, cobalt is always accompanied by nickel, although nickel may often be found without cobalt. As a colouring matter, oxide of cobalt is injured by the presence of oxide of nickel, these oxides producing colours which are almost complementary to each other; but with this ore an excellent cobalt might be produced. Ores containing both nickel and cobalt are found in Cornwall, but as they seldom contain more than from 2 to 7 per cent. of available metallic matter, while the ores on the continent frequently contain from 12 to 15 per cent., the process for the reduction which may answer very well for the richer ores may fail altogether, or prove too costly, if applied to the poorer ones. Such is the case with the Cornish ores: the Swedish method has been tried with them, and has failed; hence, there was no specimen of British zaffre in the Great Exhibition, and we import every year about 400 tons of zaffre and smalts, and nearly the same quantity of nickel and speiss, of the value of about 150,000*l.*

In the German ores, not only is the proportion of metallic ingredients larger than in the Cornish, but they are also more fusible, so that when subjected to heat in a reverberatory furnace, the earthy and metallic portions separate, in consequence of their difference in specific weights, and the siliceous gangue, with a portion of the oxide of iron, rises to the top, and can be skimmed off, leaving a metallic compound beneath, composed of arsenic, cobalt, nickel, copper, and a little iron. This compound being carefully roasted in an oxidizing furnace in contact with sand or ground flint, affords an impure silicate of cobalt and arseniuret of nickel, both marketable products. Now the Cornish ores are too poor to undergo the first fusion which is necessary to separate the siliceous matrix of the mineral without a proper flux. This should be one that can be obtained at small cost, capable of easy vitrification in the granitic matrix of the ore, and yet without action on the arseniuret of cobalt and nickel. It has been suggested by a writer in "Newton's Journal," that a similar difficulty must at one time have existed with respect to many of our copper ores, which are as poor as those now under consideration, having the same excess of granitic matrix, and hence the same necessity for avoiding the use of any agent capable of attacking the sulphuret of copper. The protoxide of iron formed from these poor copper ores by the action of heat combines with the silica of the matrix so as to produce an extremely fusible silicate of iron, permitting the sulphuret of copper to fall down, while the vitreous impurities can be raked from its surface. The suggestion is, that this oxide of iron be employed as the flux in smelting the cobaltiferous nickel ores, and it is thought that the proper application of it would enable the manufacturer to send

into the market an arseniuretted compound of cobalt, containing more than 50 per cent. of the metal.

It may be stated in connexion with this subject, that a short time ago a mine belonging to the Duke of Argyle was worked for copper, but the ore not yielding a profitable return was rejected or thrown away as rubbish. A scientific chemist now steps in, analyses the ore, and finds in it no less than 11 per cent. of nickel. A few days ago we had in our hands an ingot of pure nickel, manufactured at Birmingham from this source, and it is now being largely used in the manufacture of German silver. Such is one of the numerous illustrations of the intimate relation subsisting between science and the useful arts. The wants of the latter give healthful employment to the former; the knowledge of the one often supplies, we will not say the ignorance, but the deficiences of the other; for science herself is progressive like the useful arts, and is in fact like all human effort, which first accumulates, then generalises, and uses the last generalisation as the vantage ground from which a wider range of intellectual horizon may be viewed. Hence science has her imperfections as well as the useful arts, and when we consider what triumphs the latter had won before science even was born, we must not say that the future progress of art depends upon her voluntary immolation at the shrine of science, but that both should unite and become ministers of usefulness to humanity. The useful arts occasionally reward science with the richest and choicest gifts, (iodine and bromine for example,) and science on her part should always hold herself ready to work for the useful arts.

Specimens of Manganese from Devon and Cornwall reminded the visitor of the value of this substance in bleaching, glass-making, &c. Arsenic, which is produced in such enormous quantities in Cornwall by the calcination of arsenical pyrites, &c., was exhibited in the form of white oxide, or arsenious acid, used in patent shot, glass-making, sheep-washes, and combined with sulphur in *realgar* and *orpiment,* orange-red and yellow pigments used in dyeing and in the fine arts. At the present time the refuse ores of Cornwall could supply arsenic to almost any amount.

Sulphur was beautifully illustrated by Mr. Highley's collection, which was divided into four sections, the first of which included native sulphur in rhombic crystals, from Sicily, native massive sulphur, native *sulphur minerals*—or sources of sulphur,—such as earthy sulphur, iron pyrites, or sulphuret of iron from Cornwall, &c., white iron pyrites from Littmitz, near Carlsbad, radiated pyrites from the chalk of Surrey and the Isle of Wight, cockscomb pyrites from Derbyshire, copper pyrites in crystals from the Banat, &c., copper pyrites massive from Staffordshire, &c. Section 2 included the *crude sulphur of commerce,* such as crude Sicilian sulphur and drop sulphur. In section 3 were specimens of *refined sulphur,* such as lump sulphur, roll sulphur, sublimed sulphur, sulphur vivum (the residue after the process of sublimation), sulphur precipitatum, pure and adulterated. In the 4th section were beautiful specimens of sulphur crystals, obtained from its fusion and also from its solutions in bisulphuret of carbon, camphine, &c.

The history of sulphur as a raw material is a wonderful example of the progress of British manufactures. Although it is an abundant waste product in our metallurgical operations, yet it is found more economical to import it from the volcanic districts of Sicily, where it occurs native, than to collect it at home, at least on a scale commensurate with the national demand. At the present time Sicily furnishes us with about 80,000 tons of crude sulphur, which enormous quantity is chiefly used in the manufacture of sulphuric acid and gunpowder. There is also a large quantity used in medicine, in the manufacture of vulcanised caoutchouc, vermilion, and lucifer matches. In 1820 our whole consumption of sulphur was only 5,000 tons; in 1836, it was about 32,000 tons; in 1838, it was 44,000 tons, nearly all of which was procured from Sicily. About this time the Neapolitan government, in direct opposition to commercial treaties entered into with Great Britain, endeavoured to establish a monopoly in the sulphur trade of Sicily, the consequence of which was a rise in price from 6*l.* or 7*l.* to 13*l.* or 14*l.* per ton. In 1839, the importation into Great Britain had declined to 22,000 tons, of which, only 5,400 came direct from Sicily. The British government interfered, and the monopoly was abolished in 1840. With reference to this subject Liebig remarks:—

Reflecting on the important influence which the price of sulphur exercises upon the cost of production of bleached and printed cotton stuffs, soap, glass, &c., and remembering that Great Britain supplies America, Spain, Portugal, and the East with these, exchanging them for raw cotton, silk, wine, raisins, indigo, &c., we can understand why the English government should have resolved to go to war with Naples, in order to abolish the sulphur monopoly which the latter power attempted to establish. Nothing could be more opposed to the true interests of Sicily than such a monopoly: indeed, had it been maintained for a few years, it is highly probable that sulphur, the source of her wealth, would have become perfectly valueless to her. Science and industry form a power to which it is dangerous to present impediments. It was not difficult to perceive that the result would have been the entire cessation of the exportation of sulphur from Sicily. In the short period that the sulphur monopoly lasted, fifteen patents had been taken out for methods to obtain back the sulphuric acid used for making soda. Admitting that these fifteen processes were not perfectly successful, there can be no doubt that it would ere long have been accomplished. But then in gypsum (sulphate of lime) and in heavy spar (sulphate of barytes) we possess mountains of sulphuric acid; in galena (sulphuret of lead) and in pyrites we have no less abundance of sulphur. The problem is, how to separate the sulphuric acid or the sulphur from these native stores. Hundreds of thousands of pounds' weight of sulphuric acid were prepared from iron pyrites while the high price of sulphur consequent upon the monopoly lasted. We should probably ere long have triumphed over all difficulties, and have separated it from gypsum. The impulse has been given—the possibility of the process proved; and it may happen in a few years that the inconsiderate financial speculation of Naples may deprive her of that lucrative commerce.

Salt was illustrated by several specimens of rock salt from Northwich, among which was a splendid hexagonal block, 7 feet 4 inches round, and about 6½ feet high, exhibited by Mr. J. Thompson. The only mines of rock salt in England are in the neighbourhood of Northwich, although brine springs are not uncommon in the coal formation. At Northwich two beds are wrought, the upper of which is covered with about 110 feet of variegated marls, containing no trace of organic remains, and separated by rather more than 30 feet of similar marls from a lower bed, which has been sunk into to the depth of 108 feet. It is only in the lower five yards of the inferior deposit that the salt is sufficiently pure to be worked, the rest being much contaminated with marl. The salt is divided into globular concretions, the contact of which has produced hexagons, a portion of one of which was exhibited.

The illustrations of salt as an article of food, &c. belong to Class III., and of soda from salt to Class II.

The number of pages which we have already written on the Raw Materials of the Great Exhibition, warns us that we are exceeding our limits. We must, therefore, be more brief in noticing the raw materials of our foreign contributors, but as our colonies are second in importance only to our own country, we must give some details respecting them. Each colony was represented by a collection which quickly and eloquently informed the visitor of the natural resources of the place. We have already referred to the admirable arrangement of the Canadian collection, and the excellent written notes thereon by Mr. Logan, the director of the geological survey of Canada. The variety and importance of the minerals of Canada have only been made known during the last seven years that this survey has been in progress. Thus the existence of valuable iron ores in Canada can scarcely be said to have been previously known; and yet says Mr. Logan:—

The country abounds in the ores of iron, consisting of the magnetic and specular oxides, and the hydrated peroxide or bog ore. The first occurs chiefly in a formation consisting of gneiss interstratified with important bands of highly crystalline limestone, and the formation sweeps through the province from Lake Huron to Labrador, keeping at a variable distance north from the left bank of the river St. Lawrence and its lakes, crossing the river at the Thousand Islands below Kingston, to form a junction with a great peninsular-shaped area of the same, occupying a mountainous region in northern New York, between Lakes Champlain and Ontario. The ore appears to lie in beds running with the stratification usually highly inclined, and the beds occasionally attain a great thickness. A bed which is now worked in the township of Marmora, and of the iron resulting from which samples have been sent, presents a breadth of 100 feet; another, the ore of which has been mined and smelted at Madoc, has been traced several miles with a breadth of 25 feet; on Myers' Lake in South Sherbrooke, there is a 60 feet bed; in South Crosby, a bed 200 feet in width comes upon the Rideau Canal, where it is not far removed from great water power; and in Hull there is a 40 feet bed, at no great distance from the navigable water of the Ottawa. From all these localities and others, specimens have been contributed, and the produce of the ore in pure metal generally ranges from 60 to 70 per cent.; that of South Sherbrooke is 63, and of Hull 69 per cent Where the mineral has been acted on by the weather, it frequently breaks up with facility into grains related to the forms of the crystals of the magnetic iron ore, and may be easily ground and separated from earthy impurities by means of a machine in which the action of the magnet is made available. A portion of the Hull bed is in this condition; and of this bed, every fathom in length

by a fathom in vertical depth, taking the breadth at one-half only of what it appears to be, would produce between 50 and 60 tons of pure metal. Wood for fuel is in abundance near all the localities.

Specular iron ore appears to belong to the same geological formation; and a valuable and important bed of it occurs in the township of Macnab. It is 25 feet thick, and containing 58 per cent. of pure iron, the produce of the bed would not be under 50 tons of metal for every fathom forward by a fathom vertical; but though within a mile of the navigable river of the Ottawa, where steam-boats daily pass, and but 300 or 400 yards removed from a cascade on the river Dochart, giving ample water power to drive machinery, the bed has never been touched for available purposes. Specular iron ore occurs also on the north shore of Lake Huron; but it is here in a formation which succeeds the gneiss, consisting of quartz rock, slates, and trap, and is noted as belonging to part of the copper-bearing region of the province.

Bog-iron ore exists in large quantities in both sections of the province. In Western Canada it prevails in the county of Norfolk, where it has been used to supply the wants of the Normandale Iron Works. It occurs in many places of the valley of the Ottawa, and specimens of it have been sent from Vaudreuil, Stanbridge, Simpson, Rivière du Chêne, St. Maurice, Portneuf, St. Vallier, and other parts, where in general it yields upwards of 50 per cent. of pure metal. That of Vaudreuil, within a short distance of the navigable river of the Ottawa, yields to analysis 76.95 per cent. of pure oxide of iron, equal to 53 per cent. of pure metal, and the deposit is represented to be 4 feet thick. At the forges of St. Maurice, near Three Rivers, this species of ore has been used for upwards of half a century in the manufacture of iron. The cast stoves from it bear a high character through the country, being less liable to crack than the imported ones; and specimens of the wrought iron produced there have been sent to the Exhibition. The quality of the metal, wood charcoal being the only fuel used, bears a comparison with that of Sweden, and it is to compete with this that it is manufactured.

The geological formation which abounds in magnetic, yields also titaniferous iron, the composition of which, at St. Urbain, in Bay St. Paul, below Quebec, is oxide of titanium, 48.60; protoxide of iron, 37.06; peroxide of iron, 10.42; magnesia, 3.60. This result is sensibly the same as that obtained by Rose from the titaniferous iron ore from Ilmense in the Urals, to which he has given the name of Ilmenite. One of the masses is 90 feet wide, by a visible length of 300 feet: in some parts it consists of an admixture of ilmenite and rutile; and if the consumption of the compounds of titanium[1] in the arts should increase, the localities of Bay St. Paul might be made to furnish an inexhaustible supply. Titaniferous iron ore occurs also on the south side of the St. Lawrence, in what are termed the Eastern Townships, through which runs a continuation of the Green Mountains of Vermont. The prolongation of this range into Canada is composed of rocks belonging to the lower Silurian age, and there presents a crystalline condition from the metamorphic action of heat, displaying chloritic and talcose slates, serpentine and other magnesian forms: beds of iron ore, in general more or less magnetic, are frequently repeated among them by undulations; they prevail in the townships of St. Armand, Sutton, and Brome, where many occur, varying in breadth from 2 to 15 feet, and in produce of pure iron from 20 to 50 per cent. One of 45 feet width, occurring in serpentine in the seignory of Rigaud Vaudreuil Beauce, is a mechanical mixture of about two-thirds magnetic iron and one-third ilmenite; and when the ore is reduced to a powder these are readily separable from one another by means of a magnet. But in general those beds which occur in the chloritic slate of St. Armand, Sutton, and Brome, contain a variable but much smaller proportion of titanic iron; and several of them have been mined, and their ores advantageously transported by land distances of thirty and forty miles, to smelting establishments in the state of Vermont for the manufacture of iron. Though wood abounds in the district, none of the ores have been turned to smelting purposes in Canada.

The mineral riches of Canada are very great. Its *copper* has already been noticed at some length. It has *lead* and *zinc*, but they are not at present of much importance. There are *native silver, cobalt,* and *native gold,* in small quantities, occurring in pieces from a few grains to a quarter of a pound; *chromic iron, iron pyrites, wad* or *bog manganese,* and traces of *uranium.*

There are also many rocks and earthy minerals of great commercial value; a pure white *dolomite,* with 45 per cent. of carbonate of magnesia; *magnesite* in large quantities, with 83 per cent. of carbonate of magnesia; *barytes* is also plentiful, and there is a great abundance of *iron ochres,* giving various beautiful tints allied to sienna brown; *lithographic stone* in beds, 1 to 2 feet thick; *agates,* and a 6-feet bed of *jasper* and *jasper pebbles;* two beautiful descriptions of ornamental stone, apparently species of *labradorite* and *avanturine; white quartzose sandstone* fit for glass making; *plumbago, asbestos,* and pure *soapstone* in abundance; the latter so named from its soapy feel, and also well adapted by its sectile and refractory nature for furnace linings, stoves, baking stones, and other forms into which it is manufactured in the neighbouring States; it is actually imported into Canada in various shapes, the native quarries being neglected, except for the purpose of making foot-warmers for winter journeys: the material being a slow conductor of heat, a slab of it heated, and enveloped in a blanket, is

(1) Titanium is occasionally met with in the slag adhering to the bottom of iron blast furnaces, in small brilliant copper-coloured cubes, hard enough to scratch glass, and extremely infusible: they resist the action of acids, but become oxidized when heated with nitre. We are not aware of any application of this metal in the useful arts.—ED.

placed under the feet at the bottom of a sledge, and it will afford a comfortable degree of warmth to the traveller for a considerable time.

The province also contains mineral manures, such as *phosphate of lime*, *gypsum*, and *shell-marl*. The latter "occurs in the bottoms of ancient and of existing fresh-water lakes, and being a result of comminuted shells, is a nearly pure carbonate of lime. In four or five small lakes near New Carlisle, on the Bay Chaleur, it is composed of the calcareous remains of microscopic testacea; and being as fine and white as flour, it has been purchased by chemists for their purposes."

The country also affords such rocks as *granite* and whitish *trap*, and a *siliceous conglomerate*, used for millstones. Grindstones and whetstones are also supplied by appropriate rocks; then there is *tripoli earth*, *roofing slates*, *flagstones*, and building stones of calcareous quality. The slate is of coarse quality, but will improve in fineness as the quarries become more fully opened. At present, wood is so abundant in the colony, that shingles or wooden tiles are the usual roofing material. A beautiful white *granite*, various useful qualities of *marble*, *serpentine*, &c. also occur in abundance. *Peat*, *petroleum*, and *naphtha*; a *mineral pitch*, or *caoutchouc*, said to extend over several acres; *bituminous shale* and a number of mineral springs, complete the rich and varied mineral products of this splendid country.

New Brunswick and Nova Scotia furnish the coal in which Canada appears to be deficient, so that at some future day, when mining and smelting operations shall have exhausted the Canadian forests, she may turn to her friendly neighbours for supplies of fuel. But in respect to iron, the chief ruler of the world, Nova Scotia is not an unworthy rival of Canada. Her iron ores are of great richness and purity; several of the specimens exhibited yield upwards of 70 per cent., are free from sulphur and other objectionable impurities; and are situated in the midst of vast native forests capable of supplying charcoal at a cheap rate. The mode of reduction is what is called the Catalan process, by which the ores are directly converted into bar-iron with charcoal fuel. Steel is also made direct from the ores. The principal mines are within four or five miles of ship navigation, and in juxtaposition with the ores are found coal, lime, marble, freestone, fine clay, timber, water-power, and every requisite for manufacturing iron on a large scale. The specimens exhibited were intended to illustrate the proposition, "that the province of Nova Scotia is capable of supplying the whole British Empire with steel and charcoal iron, equal to the best foreign articles, and at greatly reduced prices." The manufactured iron consisted of cast and pig, grey, mottled, bar, rod, steel-iron, horse-nail, &c.; turned specimens, polished bars, tin-plate, wire, dies, &c. Also steel bars, wire, &c.; fenders, fire-irons, sword blades, knives, scissors, surgical instruments, magnets, pistols, files, edge tools, razors, &c. The marble of Nova Scotia was of fine texture and good colour, but not very close or even grained. There was some good freestone; also gypsum and its interesting crystalline variety selenite; also grey copper ore and native copper; oxide of manganese; fossils of the carbonaceous series, and a lump of good bituminous coal.

New Brunswick contributed iron-ore, manganese, plumbago, and pitch coal. These, however, represented but inadequately the mineral wealth of a country larger than Ireland. Her population is at present too much occupied in cutting timber (*lumbering*), and fishing, to attend to mining. Indeed, the contributions of several of our colonies were indications rather of future wealth and enterprise than of works actually commenced and in operation. Thus in contemplating the small collections sent by Trinidad; the pitch, petroleum, and mineral oil from its extraordinary lake; its lignite and anthracite; its slate; its magnetic and hæmatitic iron ores: New Zealand too, with her lignite, anthracite and bituminous coal limestone, cement stone, building stones, iron and copper ores: Bermudas, her mineral wealth represented by a solitary specimen of pumice stone: British Guiana, sending only a few clays and sands, the latter adapted to the wants of the glass manufacturer; and some of our colonies not contributing a single mineral;—in regarding, we say, these small and unpretending collections, and remembering that many of the countries which contributed them are blessed with fine climates, navigable streams and water-power, splendid harbours, and abundance of raw material, the mind wanders into the future, and contemplates those wide forest tracts and those

extended plains, those hills, valleys, and streams reechoing with the sounds of our well-beloved English tongue, the children of our dear fatherland converting these solitudes into smooth and sunny paths over which civilization and her attendant blessings advance with gradual but sure steps. Such a prophetic picture as that drawn by the poet Schiller, might well be appended to many of the infant States, so inadequately, and yet so suggestively represented in the Great Exhibition :—

> Commerce awakes, by freedom inspired, by security nurtured;
> Beckons the azure god, pleased, from the reeds of his stream.
> Gashing, the broad axe flies—while the Dryad shrieks—and in ruin
> Down from the mountain's brow crashes the thundering tree.
> Wing'd by the lever's force, the stone nods forth from the quarry,
> Deep in its innermost gorge plunges the miner beneath.
> Hark to the rude Vulcanian music from anvil and hammer,
> Where at each nervous blow flashes the bickering steel:
> Hark to the whirling reel, with its flaxen burden surrounded,
> And the swift shuttle's play, brushing the warp as it flies.
> Hark to the pilot's hail in the distant road, where a navy
> Waits to transport abroad industry's costly results.
> Others arrive, deep laden, from far, and jovially cheering,
> Garland and streamer on high float from the towering mast;
> Rises o'er all the mart's busy din—the bustle of commerce;
> Barbarous tongues uncouth strike on the wondering ear.
> Hither the harvests of earth are consign'd. Here heapeth the merchant
> All that Africa's soil yields to the ripening sun;
> All that Arabia distils—all uttermost Thule can proffer;
> Fair Amalthea's horn brims with exuberant wealth:
> Wealth which, to Genius wedded, a godlike offspring produces—
> Arts, which strengthen and grow, nurtured by freedom and taste.
> Charming the sight with emulous life, spreads the painter his canvas,
> And by the sculptor inspired, feels the cold marble and speaks.
> Sky-like vaults scarce press on the slender Ionian column,
> And a Pantheon's dome swells—an Olympus on earth!
> Light as the rainbow's leap—as the vaulting flight of the arrow,
> Bounds the self-balanced bridge, yoking the torrent beneath:
> Science, the while, deep musing in cell over circle and figure,
> Knows and adores the Power which through creation it tracks,
> Measures the forces of matter—the hates and loves of the magnets;
> Sound through its wafting breeze, light through its æther, pursues;
> Seeks in the marvels of chance the law which pervades and controls it,
> Seeks the reposing pole, fix'd in the whirl of events.
> Speechless thought takes body and voice from the craft of the penman,
> Down the long stream of time borne on the eloquent page.
> Fast from the wondering sight the mists of error are clearing;
> Chased by the dawning beam fly the dark spectres of night.
> Burst are the chains which fetter'd mankind. O happy! if only
> Bursting the chains of fear, kept they the bridle of shame.

India, Ceylon, and the British possessions in Asia approach the Great Exhibition under very different circumstances to those in which our North American colonies appear. They had attained a high degree of civilization and refinement long before Britain had acquired a footing on their soil. Their native manufactures were in constant requisition for supplying the rest of the world with costly articles. Abundance of new materials, raw and manufactured, came under the notice of the conquerors; and although we have traded so long with India, and been so long masters of its extensive territory, we are still but imperfectly acquainted with the extent of its productions, and the benefits it has yet to confer on the useful arts. It was only a year or two ago that Gutta Percha became known to us, and the splendid and useful Indian collection in the Great Exhibition has revealed many other raw materials hitherto imperfectly known or not known at all: many specimens of native ingenuity and skill capable of informing the mind and improving the taste of our art-manufacturers.

Dr. Royle, one of the gentlemen to whom were entrusted the arrangement of this magnificent collection, remarks :—

> There appear to be only two available methods by which a manufacturer can be made acquainted with the existence of foreign products likely to be useful in his business: one is by the collection of such information as is obtainable respecting them, and arranging it according to the most prominent properties of

such substances. When these are so arranged, it is comparatively easy for any one to ascertain whether India, or any other foreign country, contains any useful or ornamental product which might be employed instead of, and be cheaper than that already in use. But with the most simple arrangement and clearly-conveyed information the manufacturer generally would feel little interest about unknown natural products and their strange names, unless he had an opportunity of seeing and of personally examining them. Then a glance of his practised eye, or the slightest handling of a new substance, informs him whether it is likely to be of use for his purposes. The collection, therefore, of such substances, and arranging them also, as above, according to their properties, is the only method calculated at once to interest the public and to give such confidence to the manufacturer as to induce him to submit them to trial. Their exhibition, therefore, is calculated not only to be of great use to the manufacturer, but of essential benefit to such countries as possess many little-known products endowed with valuable properties and procurable in large quantities at a cheap rate, if a demand could be created for them. As India produced the raw material and also manufactured it into a costly article, gold and silver have from the earliest times been required to purchase this combination of the gifts of nature with the creations of art; but mechanical invention has deprived the Hindoos of many of the advantages of their position, and they have in a great measure lost the commerce which they had themselves created, especially as some of their products were subjected to discriminating duties, which amounted to a prohibition on import into this country. Hence their foreign commerce has not advanced as might have been anticipated, from the enjoyment in many parts of long-continued peace. But fashion, which here is as fickle as the wind, is in the East as steady as their monsoons, and has fortunately preserved some of their manufactures in their pristine excellence, and which in any general collection of manufactures would enable those of India still to hold a conspicuous place.

The Court of Directors of the East India Company fully patronised and encouraged the formation of such a collection as should fairly represent in the great gathering of all nations the industrial resources of the wide realms of which they are the rulers, wisely conceiving that there would be mutual advantages of great importance both to India and to this country; to India in calling forth new products, and to this country in furnishing suggestions and new materials for manufacture. In the instructions sent out to India, the Court called the attention of the Indian Government to the occasion when an opportunity would be offered for the latent resources of distant provinces, and the skill of the least known artist, to compete with the produce of the most favoured regions, or the works of the most successful genius. "It is our wish, therefore, that the objects of the proposed exhibition should be made known as generally as possible throughout India, and that our several governments, and those of our servants, whose station or pursuits may afford the opportunity of their so doing, should use their endeavours in order to the formation of such of the raw products and manufactures of India as may not only be interesting in a scientific point of view, but may also be subservient to the purposes of commerce and art."

The zealous cooperation of the Company's servants in India, assisted as they were by a number of intelligent natives in different parts of India, had the effect of bringing together such a collection as few persons who had the privilege of studying it will forget. We can here notice only a few of the mineral products. First, there were specimens of the magnetic iron ores from Salem and South Arcot, from which *wootz*, or Indian steel, is manufactured by the natives, and also malleable iron by the direct process. The ore when freed from quartz contains 72 per cent. of iron and 28 of oxygen, with traces of manganese and lime. The manufacture of iron in India from these ores, by European methods, was established some years ago, by the Indian Iron and Steel Company of Beypore, on the Malabar coast, and at Porto Novo in the Carnatic. The Company exhibited specimens of pig-iron (which is largely imported into Great Britain), and of the charcoal used in the manufacture. Also castings from the refined pig-iron, specimens of wrought-iron, iron-wire No. 7 to No. 30, screws, nails, axles, &c., and bar-iron for steel purposes, cast-steel ingots, files, saws, razors, blades, &c. There were also specimens of chrome iron-ore, and samples of chromate and bichromate of potash manufactured therefrom. There was also the iron-ore and iron from Cutch, manufactured by the natives, by a process which is practised everywhere from the Himalaya mountains to Cape Comorin, and was probably witnessed by the soldiers of Alexander at the time of his invasion. In this process the ore and the charcoal fuel are disposed in alternate layers in a rude open furnace, and the workman urges the blast by means of two small bellows made of sheep-skin.[1] The reduced metal, or *bloom*, is received into a hole at the bottom of the furnace, when it is transferred to an enclosed furnace, and raised to a white heat; it is then taken out and beaten

(1) See Bellows and Blowing Machines in the Cyclopædia, Fig. 122, p. 124.

into a bar. No flux is used; the oxygen of the ore combines with the carbon of the fuel, leaving the metal free. 140 lbs. weight of iron can be manufactured in this way at an expense of 32 corries, or 16*s.* A cart-load of mineral, after 18 hours' smelting in the open furnace, yields 10 maunds, or 280 lbs. of pig-iron, and that again yields 5 maunds, or 140 lbs., after 9 hours' smelting in the closed furnace.

The iron-ores from other parts were also numerous. There was manganese, antimony, copper, lead and tin from the Tennasserim coast, Cinnabar,[1] orpiment from Nepal, gold-dust from Singapore and Nepal, bell-metal from Bellary, and pewter from Nepal.

A very large collection of agates and carnelians was contributed from the eastern and western points of the central zone, from the Saone and Kane rivers on the one side, and from Cambay on the other. There were specimens of these in the rough and polished states, and also as worked by the native lapidaries into a great variety of useful and ornamental articles. The information accompanying them is interesting, and we may quote that portion relating to *carnelian* as a useful addition to our article on the subject in the Cyclopædia.

Carnelian is named *gharr* in the original state. Some of the stones are cloudy, of various shades of brown, and others of different tints of yellow. After exposure to the sun and baking, these assume other tints, as follows :—

Light brown becomes white, *dholu,* pale yellow, rose colour, *gulabi,* deep yellow. Red or *lall,* a mixture of cloudy brown and yellow, becomes white and red, named *ubluckee;* another shade of yellow turns pinkish purple, named *nafurmaric;* and brown becomes a darker shade, named *emni.* The above are quarried in large quantities, and undergo the process of baking; they receive a high polish, and are wrought into flat and round necklaces, bracelets, armlets, stones for seals, chessmen, marbles, studs, rings, &c. . . Between the Bowa Gore and Bowa Abbas hills, on the plain, are small mounds, from whence the stones are quarried by the Bheels of the district: they excavate to some depth, forming galleries in a horizontal direction about five feet in height and four broad; they are obliged to use a lamp and work in pairs, one employed with the pickaxe in the quarry, the other at the entrance, who examines the stones by chipping off a piece, retaining the good, and rejecting the bad on the spot. When a larger number of men are employed, the galleries are extended in different directions, with air passages. The two men in eight or ten hours obtain from 10 to 40lbs., which is bought in the village of Ruttenpore by the contractor or his people. A quantity is thus procured in the fields; after which many generally dig a trench round a field two feet in depth, and three in breadth. In this fires of goat's and cow-dung are set up, and the stones in earthen pots in single rows are placed in the trench; the fire is kept up from sunset to sunrise, when the chatties are removed and the stones piled away. The contractor attends to the heating process. The stones are once a-year carted to Nemodra, and conveyed in canoes down the river to Brouch, whence they are brought in boats to Cambay.

Although the agates and carnelians still bear the name of *Cambay* stones, and this place has held the reputation for a considerable time of being famed for its stone quarries, they are actually brought here in the rough state from different parts of Guzerat, and are only wrought in the lapidary workshops established here for upwards of a century; and although the value of the traffic has been considerably reduced of late years, it still forms, next to cloth, the principal article of commerce, yielding a good profit to the traders, forming a valuable source of revenue to the state, and giving employment to nearly 2,000 people in the manipulation of the articles in the busy workshops, amounting in all to about seventy-five large and twenty-five small shops.

The following is the native process for making agate beads:—the stones are first broken into pieces of the size desired; an iron spoke is driven into the ground in an inclined direction, with one point upwards; the stones are placed on this point and chipped with an iron hammer till rounded. They are then passed on to the polisher, who fixes a number of equal size in a pair of wooden or bamboo clams, and rubs them on a coarse hard polishing-stone. They are next transferred to another man, who, securing them in wooden clams, rubs them against a ground polishing board, on which is smeared a composition of emery and lac, turning the beads round so that every part of the surface may assume a globular form, and become polished. The final polish is given by putting from one to several thousand of the beads so prepared into a stout leathern bag, about two feet long, and from ten to twelve inches in diameter, with some emery dust and a very fine powder, which is the sediment of the carnelians deposited in the earthen dish partially filled with water during the process of drilling holes in the beads, which is always collected and dried. The mouth of the bag is tied up, and a flat leathern thong or tape is passed round its centre, and the bag is rolled backwards and forwards between two men seated at opposite ends of a room; this is continued from ten to fifteen days, the bag being kept moistened with water. When the beads have taken a bright polish, they are passed on to the people who bore the holes, which is effected by means of a steel drill, tipped with a small diamond, during which process the spot is fed with water drop by drop, passed through a thin narrow reed or metallic tube.

Such is the painful and laborious process by which such trifling articles as beads are produced. The time of the mechanic must be of very small value when he is thus converted into a mere machine. Indeed, there were many proofs in this collection that the wants of the

(1) The Cinnabar from Surat is said to be superior to the China vermilion.

labourer must be very few and easily supplied, or he could not devote the time required for elaborately inlaying *iron* articles with silver, and executing such varied and complicated works —many of them mere toys—in wood, ivory, metal, and stone.

Specimens of coal were sent from the deposits which stretch across India from east to west, viz. from Assam into Silhet and Burdwan, and along the course of the Nerbudda, as well as in the western district of Cutch. There were specimens also of lignite and petroleum; mineral resin or amber dug up with the coal; salt from the salterns of Vizagapatam and Coombaconum; Bootan rock salt; alum and alum shale from Cutch; sulphur and saltpetre from Nepal, &c. There were also various specimens of marble, limestone, serpentine, and building stones; graphite and lithographic stones; pipe-clay, yellow ochre, and clay from Singapore; fossil trees from Nerbudda; fossil woods from Assam; petrifactions and petrified woods from Bengal and Mirzapore.

The Madras Presidency contributed a fine collection of minerals, numbered from 1 to 332. A variety of kaolins, or porcelain earths, were of interest and importance: the clays were also numerous. There were besides, specimens of talc, magnesia, baryta, and salt; marbles and limestones; granite and syenite; porphyry and slate; a great variety of iron ores and ochres; gems and precious stones; ultramarine prepared from the lapis-lazuli from Bombay; lake prepared from madder from Chingleput.

The mineral contributions of Ceylon were but limited. The riches of the surface appear to be at present abundantly sufficient to engage the industry of the natives, without penetrating into the interior. There is, however, abundance of iron and manganese; there is plumbago, soft but very pure; there are natural deposits of salt; nitre is also found in caverns, and there are many gems, such as cat's-eye, ruby, and sapphire.

It will be seen by reference to the plan that India occupied a large space on both sides of the western nave. Between India and Ceylon, on the northern side, stood Malta, from which the only specimens of raw material were some pieces of stone, oiled for pavement, and in their natural state. There were, however, several vases and ornaments made of stone from Malta and Gozo. These two islands consist of stratified tertiary deposits, including, in descending order, 1. A coral limestone, with cretaceous nodules, some of which are variegated with yellow and white, and are used for ornamental work under the name of *Gozo marble*. 2. A sandstone and blue clay, containing iron, gypsum, and sulphur. 3. Five beds of freestone, chiefly calcareous, but with sandy admixture, much used for building in all parts of the Mediterranean. 4. A yellowish-white semi-crystalline limestone, also used for building purposes.

The mineral contributions of the Channel Islands spoke of a primary formation. The granites of Jersey were well arranged. These are extensively quarried for building purposes; and both the granite and the syenite show a fine grain, and are very durable. Several of the London streets have been paved with this granite, and some of the finest varieties have been selected for monuments. Specimens of gneiss, greenstone, and hornblende were also exhibited; as well as steatite, or soapstone, a magnesian rock, used in the manufacture of porcelain, and for polishing stones and glass.

The Ionian Islands can scarcely be said to have been represented in the Exhibition. A few articles, chiefly ornamental, were collected from persons officially connected with or interested in the islands, but there was no local committee, and no move on the part of the inhabitants.

South Africa contributed lead ore from the Maitland Mines, Port Elizabeth; iron ore, and oyster shells, from Uitenhage; graphite, from Capetown; coral, from Caledon; and a slab of coloured marble, from Natal, mounted as a table on a stand of oak.

St. Helena contributed some limestone, and a few fossil shells.

The copper of South Australia has already been noticed. This fine country also contributed a splendid collection of opals, including not less than forty varieties. There was besides a fine sample of beryl lying in quartz; also chalcedony, marbles and hone-stone; *jade*, a tough stone, of which savage tribes form their edge-tools and battle-axes; granite with beryl; gneiss with beryl, both showing the component parts of the parent rock. Western Australia sent coal from the Swan river, porcelain clay, garnets, fine lead-ore, and some copper-ore. Van

Diemen's Land contributed coal from Douglas River. Coal appears to have been traced over a large area of country on the east coast of the island; plumbago of fine quality from Norfolk plains was also exhibited; also granite, porphyry, and limestones; clay iron-stone, found in beds alternating with bituminous coal; magnetic iron-ore; also an iron-ore found in nodules with quartz in a granite soil; it was formerly used by the natives as a paint, being first peroxidized by roasting, and then ground to a fine powder between two stones. Specimens of manganese and galena, topaz, ochres and chalks were also exhibited; also thirty specimens of aquamarine, or beryl, in pebbles, varying from soft to very hard, and from blue to light green; numerous specimens of straw-coloured, yellow, and pink topaz from Flinder's island, and a sample of greenstone with impressions of ferns.

Some specimens of silicized wood from Macquarie Plains, 32 miles from Hobart Town, excited considerable attention. The tree, when discovered, "was 12 feet high, imbedded in lava, and distinctly surrounded by two flows of scoria, which at some distant day had brought out the juices of the tree to its surface, and became, by a combination of silex, completely vitrified, and surrounded the tree with a glossy surface, the interior of the tree producing opal-wood." Dr. Hooker has declared it to be a pine, a species of tree not growing in the neighbourhood. "It is conjectured that it was originally thrown up by an eruption of a volcano to a considerable height, and came down with its heavy end first upon a bed of sand, and had remained there for ages. . . . . . The manner in which the outer layers of wood, when exposed by the removal of the bark, separate into the ultimate fibres of which it is composed, forming an amianthus-like mass on the ventricle of the stump in one place, and covering the ground with a white powder, commonly called *native pounce*, is very curious." The tree was excavated and removed at great expense and labour. It was in a perfectly perpendicular position on the point of a ridge of rocks.

The specimens of mineral wealth contributed by Australia are suggestive of future rather than present prosperity. Many generations will probably pass away before these fine countries will be sufficiently peopled to take advantage of their riches, the specimens of which are well calculated to awaken a sublime train of reflection. The geological history of these splendid countries reveals to us the preparation and arrangement of valuable minerals in a determinate order, so that by certain indications at or near the surface the eye of science can form a just estimate of their value, and guide the hand of industry to well-directed exertion; but between the deposit of these treasures and their industrial application, how vast the lapse of time, calculable only by Him to whom "a thousand years are but as one day," whose omnipotent mind scanned the interval, and connected the geological formation with the existence of thriving communities busily exercising the industrial arts, and joining also, let us hope, in the inspired song which calls upon all created things to "praise the name of the Lord, for He commanded, and they were created."

It is remarked by Humboldt that "when, far from our native country, after a long voyage, we tread for the first time the soil of a tropical land, we experience a certain feeling of surprise and gratification in recognising, in the rocks that surround us, the same inclined schistose strata, and the same columnar basalt covered with cellular amygdaloids, that we had left in Europe, and whose identity of character, in latitudes so widely different, reminds us that the solidification of the earth's crust is altogether independent of climatic influences."[1] A similar feeling was experienced by the visitor to the different foreign departments of the Great Exhibition: he found that a great variety of foreign minerals were identical with those exhibited in the British sections, and not inappropriately moralizing on the subject, finding

"Sermons in stones, and good in everything,"

it might have occurred to him that the inhabitants of the countries represented by these masses of inorganic matter are identical with ourselves in past origin, in present pleasures, pains, hopes, fears and sympathies, and in future destiny; accountable to the same great Power for the

(1) Cosmos: Introduction to Vol. I.

use or abuse of entrusted talents, and for the obedience to or neglect of the Divine command, "Love one another."

But as we naturally feel the greatest interest in those nations which most closely resemble ourselves, who speak the language of Shakspeare and Milton, whose forefathers breathed the free air of Britain, and whose institutions are conceived in the spirit if not quite in the form of our own, we turn first to that splendid portion of the earth's fair surface, the United States of America. The rapid development and the still increasing progress of this great country from the year 1783, when it first took its place among the nations of the earth as an independent people, are matters for astonishment and admiration. All the natural and political advantages enumerated in Section II. of this Essay, which have raised Great Britain to her present high position, belong especially to the United States. She has noble rivers, and water communication with the rest of the world. From a large extent of Atlantic coast she can communicate with Europe and Africa: from the Mexican Gulf she can transmit her products to South America: from the Pacific shore, from Oregon to South California, the wealth of the interior finds an outlet to the westward as far as China: while the northern lakes afford means of easy intercourse with her northern states as well as with Canada. Her mineral wealth is in great abundance, and that portion of it which is best known lies in vast basins upon inland waters admirably adapted for the purposes of navigation and ready communication with one or more of the above-named shores. Hitherto the industrial efforts of the United States have been directed chiefly to agricultural pursuits, her vast and rapidly increasing population rendering an abundant supply of food a matter of first-rate necessity; hence mining and manufactures are only beginning to be developed, and the objects exhibited at the Great Exhibition spoke rather of an agricultural than of a great manufacturing people. But as new tracts become peopled, the most accessible raw materials will be gradually worked. When the immense forests of the United States begin to show signs of exhaustion, her vast stores of coal will come into use. The extent of this coal (a large proportion of which is anthracite) has been estimated at no less than 133,132 square miles, or one-seventeenth part of the whole surface, whereas in Great Britain the coal area is under 12,000 square miles. Most of the useful metals also exist in great abundance, and two of the specimens contributed were characteristic of the large scale upon which nature displays herself in this fine country: we allude to the immense mass of zinc ore and the huge lump of native copper already described. As population increases, the iron wares of Pittsburg will descend in increasing quantities along the shores of Lake Erie and the valleys watered by the Ohio: the lead of Missouri will supply the wants of settlers for thousands of miles along the course of that river and its gigantic neighbour the Mississippi, as well as along the shores of Michigan and Superior; while the coal in the eastern valleys of the Alleghany district will be in brisk demand from nearly all quarters around them. These vast stores of mineral wealth were very inadequately represented in the Exhibition: the mining companies who raise, and the manufacturers who smelt the ores and manufacture the metals, scarcely taking a part in the world's industrial display. Had it not been for Dr. Feuchtwanger's admirable collection, the minerals of the United States would scarcely have been represented at all. In the preface to his catalogue the collector expressed a hope, which was certainly realized, that his collection would not be found the less interesting from the fact that the objects were exclusively American, and might tend in some degree to illustrate the hidden treasures of the United States and the beneficence of an Almighty Providence in blessing this country with a profusion of almost every elementary substance, found only in part in any other portion of the world. In this collection was the splendid mass of copper already noticed; also a gigantic specimen of cinnabar from California: magnificent quartz geodes, crystals of tourmaline in quartz, a specimen of phosphate and carbonate of lead, a beautiful collection of ores, consisting of zinc, iron, copper, cobalt, chrome, manganese, plumbago, titanium, tungsten, &c.; also specimens of white felspar, talc, soapstone,[1] glass-makers sand of extraordinary purity, &c.; beryls

(1) The soapstone from the Baltimore quarries, Maryland, is almost as readily worked as the soft woods, and with similar tools. Indeed it is applied to many of the purposes of wood, to which in some cases its superior durability renders it preferable. One of its most important adaptations is the making of sizing rolls for cotton-mills.

of large size, topaz rocks, two cabinets of gems containing two native diamonds of $3\frac{1}{4}$ and $2\frac{1}{4}$ carats; some valuable specimens of Californian gold,[1] crystals of copper, gold, platinum, &c.; also a specimen of argentiferous lead from a mineral district in New Hampshire near the Canadian boundary, occupying an area of 15,000 acres, and intersected by a line of railway: it is stated that this galena yields from 90 to 100 ounces of silver to the ton, and 75 per cent. of lead. Coal was exhibited in many varieties, slates, and vegetable impressions in coal shales. Chalk, such as occurs in such abundance in England, is not found in the American continent; but there was in this collection a specimen of white clay from Georgia which appeared to be to a great extent calcareous. There were a few specimens of limestone and marble; but no building stone; a deficiency arising, not from want of supply, but from the present superior importance of timber.

The indifference of the mining companies and large manufacturers of the United States to exhibit, met with a few honourable exceptions. Thus the Adirondac Manufacturing Company exhibited specimens of iron and steel, pigs of decarbonized metal, bars of iron, and specimens of cast-steel. The iron-works which produced these specimens are situated in the town of Newcomb, Essex County, New York, at the sources of the Hudson River, about 40 miles from Lake Champlain, whence there is water or railroad communication with all the principal markets in the country. During five months of the year snow lies on the ground, and furnishes good roadways for transporting the iron down to the lake, but it is proposed to form a line of plank roads, or even of railroad, between the works and the lake. The ore is said to contain 70 per cent. of iron,—to exist in mountain masses, being quarried like granite. There is abundance of wood fuel at Adirondac, and excellent water-power.

The Missouri Iron Mountain Company exhibited specimens of iron-ore, pig metal, and bar-iron. The ore is taken from a bed forming the top of a hill, 600 yards from the furnace. The bed measures 500 feet from east to west, 400 feet from north to south, and 60 feet thick. It rests upon sandstone, and extends therefrom to the surface, in strata varying from 2 to 10 feet in thickness, with thin layers of clay, and occasionally of flint, interposed.

Spathic iron-ore was exhibited from Connecticut, where there exists a remarkable mine of this valuable ore, which, till a very recent period, was entirely neglected.

The mine was discovered at a very early period in the history of the state; and the abundance and peculiar properties of the ore excited a high degree of curiosity and expectation. Numerous attempts were made to work it as a silver mine, and immense sums expended without exciting even a suspicion of its value for iron. Spathic iron is one of the most disguised of all the ores of iron possessed of economical value. Its high specific gravity, added to the development of iron rust occasioned by exposure to the weather, are the only properties by which its ferruginous character is generally detected. Its name of spathic (or sparry) iron was bestowed in allusion to its brilliant and easily effected cleavages in three directions, and which result in rhombic fragments of constant dimensions. Its hardness is greater than that of calcareous spar; and its colour, when freshly raised, is a light yellowish grey, which passes, by exposure to the air, to a reddish brown. It is composed of protoxide of iron from 57 to 60 per cent., carbonic acid 34 to 36 per cent., with a proportion of manganese from 0·5 to 1·5, and about the same quantity of lime and magnesia. The spathic iron mine in question occurs in a mountain about 350 feet in height, situated on the western bank of Shepang River, in Rosbury, about four miles above its junction with the Housatonic. The mountain is known in the vicinity by the name of Mine-Hill. The rock of which it is composed is, for the most part, concealed by a soil supporting a fine growth of hard wood. Wherever the rock makes its appearance, however, it exhibits a remarkable uniformity in character and arrangement. The direction of the strata is nearly north-east and south-west, with a dip of 25° or 30° to the north-west. The ore occupies a perpendicular vein from 6 to 8 feet in width, cutting directly across the strata; and has been detected at numerous places from the base of the hill near the banks of the river quite to its summit, a distance of above half-a-mile. The course and width of the vein, wherever exposed, appear uniform.[2]

The application of zinc to the manufacture of paint was well illustrated. It is made from zinc-stone from Virginia, which consists of zinc 25 parts, carbonate of magnesia 11·21, silica 28, alumina 17, &c. It is found near the surface of the ground in a solid rock, which, when

(1) Specimens of Californian gold were exhibited from the opening of the Exhibition, but they were all eclipsed on the 27th September by the arrival of a huge block of quartz rock, impregnated in every part with pure gold. The owner, who refused to part with it for 3,250*l.*, brought this specimen to England for the purpose of procuring machinery to work the vein in which it was discovered.

The recently discovered gold mines in Australia were represented in Class XXIII. No. 51.

(2) Dr. Shepard's Geological Survey of Connecticut, quoted in the Official Illustrated Catalogue.

pulverized and mixed with oil, and applied to any surface, forms, in a short time, and in proportion as the oil dries out, a hard closely adhering stone coating, impervious to water and proof against fire. Its colour varies from a light drab to a dark brown. It admits of a fine polish, and is said not to crack from the influence of cold or heat. Another specimen of fire-proof paint is prepared from a peculiar clay found in Sharon County, Ohio. The bed is about 20 feet below the surface, and about 16 feet thick, lying in a horizontal position between rocky strata. The material has the appearance of the purest indigo. When first taken from the bed, it is soft as tallow, but becomes as hard as a stone by exposure to the air. In this state it is ground to a fine powder and mixed with oils. It is applied in the usual manner, and when dry, affords a water and fire-proof coating. It is susceptible of high polish, and is hence well-fitted for the *priming* of coach bodies, for which purpose it is imported into the United Kingdom. It consists of silica 54, alumina 24·20, protoxide of iron 12·05, lime 2·31, magnesia 2·42, carbon 1·50, sulphur 0·11, water 5.

We will conclude this brief notice of the United States mineral productions, by referring to what is called *America polish*, prepared from a chalcedonic rock, found in the state of Vermont. Silex is its chief constituent. It will cut glass, and scratch the hardest steel. The polish is an impalpable powder, said to rival emery in quality.

In proceeding to notice the mineral productions of other foreign countries, we will take them nearly in the order in which they stand in the Official Illustrated Catalogue. And first, with respect to Austria. This fine country exhibited a neat and well-ordered collection; wanting, however, in that variety which her real mineral wealth is so well calculated to afford. For, in the words of her own commissioner—

> Austria abounds in every description of metal; all the more useful kinds, with the exception of platinum, are to be found therein; and in the production of the precious metals Austria is surpassed by Russia alone. Transylvania is one of the richest countries of Europe in gold; Hungary, also rich in gold, is still richer in its yield of silver. Bohemia ranks next to Hungary in this respect, and Transylvania immediately after Bohemia. In the production of quicksilver Austria, by reason of her possession of Carniola, stands next to Spain. Bohemia supplies excellent tin, Carinthia the purest lead, and Hungary is extremely rich in copper. Iron is produced throughout the countries of this empire, the only exceptions being Görz and Gradisca, Illyria and Venice. Styria is preeminent in respect both of the quantity and the quality of its iron, which is considered equal to any raised in Europe. Fossil and brown coal the Austrian dominions may be said to possess in inexhaustible abundance, and in consequence mining has been carried on in these regions with peculiar spirit and energy. Due advantage has been taken of the progress of modern science in so pushing the advancement of this branch of the national industry, that though it cannot be said to have attained the utmost degree of development which it may be capable of reaching, yet it must be allowed to have closely approximated to it.

Who would suppose, after reading these words, that Austria is one of the poorest nations in Europe? With all her natural advantages, she must remain so until she bestows upon her people the blessing of free institutions and unrestricted commerce. In this department indications of monopoly were to be traced, which cannot fail to be highly injurious to the welfare of the people at large. For example. the bricks exhibited by Alois Miesbach were accompanied with certain pictorial and written details which may admit of an interpretation injurious to the interests of the country, and beneficial chiefly to the monopolist. It is stated that—

> This exhibitor has seven brick manufactories, giving direct employment to 4,880 persons, and producing annually 107 million bricks and tiles. His establishment at Inzersdorf, on the Wiener Berg, is the largest in the world; it covers 265 English acres, has 24,930 feet in length of drying sheds, 8,304 feet in length of moulding sheds, 446 moulding benches, 43 kilns capable of burning together 3,510,000 bricks at one time, five Artesian wells, blacksmiths', carpenters', and wheelwrights' shops, besides an infant shool for 120 children,[1] and a hospital with 52 beds; it employs 2,890 persons, and turns out annually 65,500,000 bricks and tiles; 680 English acres of land supply a first-rate material for the manufacture, and contain sufficient for several centuries. The other six factories are provided on the same scale.

The same exhibitor is also the most extensive coal owner in the empire. His 30 mines are said to contain a store of, at least, 900,000,000 cwt. of coal; whereof 864,000,000 have been discovered by himself. They give direct employment to 1,961 men; produce annually 2,750,000 cwt. of coal, and are already in a condition to produce four times that quantity.

(1) This appears to be a very small allowance of education for so large an establishment.—Ed.

The prices of wood and charcoal in Austria are constantly increasing with the annually increasing demand for fuel; so that it is probable the coal will become more and more used. A large proportion of the fuel used is lignite, which exists in enormous thick detached beds.

Almost every part of the Austrian *iron* manufacture was represented. Bohemia, Moravia, Styria, Lower Austria, the Tyrol, Carniola and Carinthia, sent specimens of their several iron productions, commencing with the raw produce in different stages of preparation, sheet and wire, and finished manufactures. Some remarkable examples of the fine rolling of iron were exhibited. Some *iron-paper*, as it was termed, from Neudeck, in Bohemia, excited considerable attention, and stimulated some of our iron-masters to the production of a similar article, which is of importance to the button-maker. Before the Exhibition closed, we had the satisfaction of examining, in Class XXII. of the English department, a book of iron-paper, containing 44 sheets, weighing $2\frac{1}{2}$ ounces, and being, when compressed, $\frac{1}{16}$th inch thick: each leaf was $\frac{1}{700}$th inch thick. The rolling was executed by Mr. Charles Hood: the exhibitor was Mr. Geo. Downing, of the Crown Iron-works, Smethwick. The Austrian steel, known in England as *Milan steel*, is in great demand; so much so, that the scythe-makers complain of want of material. The Austrian scythe and sickle have for centuries past been manufactured with great care, and at small price: they find their way into most of the countries of Europe, and also across the Atlantic. The principal seats of the manufacture are in Upper and Lower Austria, Styria, and part of the Tyrol: the annual produce is said to be about 7,000,000 scythes, sickles, and straw-cutters. Specimens of the various shapes and sizes used in different countries were exhibited. The *copper* found in Austria is not equal in quality to the Russian or Swedish copper, so that the finer sorts are imported. A large quantity of *mercury* is produced at Idria, in the duchy of Carniola. The quicksilver mines are very productive: the ore is cinnabar, or sulphuret of mercury, and the metal is produced by sublimation of the ore. In connexion with these mines is a manufactory of *vermilion*. *Tin* is not found in sufficient quantity in Austria to meet the demand for it. Ores of *cobalt* and *nickel* have recently been obtained on a large scale in Hungary, and are admirably adapted to the manufacture of German silver. Specimens of the metal *vanadium*, discovered in 1830 by a Swedish chemist, and named after the Scandinavian deity, *Vanadis*, were exhibited from Prague. It has a silvery lustre, and is extremely brittle: in combination with an acid, it produces a superior writing-ink.

The Zollverein, or *Customs Union*, is the union of twenty-six Germanic states, which, on the invitation of Prussia, in the year 1828, agreed to the adoption of one uniform rate of customs and duties. Previous to this, each state had its own tariff; so that goods and passengers, in passing through Germany, were subjected to the delay and inconvenience of being stopped at the frontier of every little state, for search, and the adjustment and payment of toll; and, as a different system of laws, coinage, weights and measures, subsisted in each, the delay and inconvenience were very great. Under the present arrangement, there is only one search for the whole of the twenty-six states. The Zollverein embraces two-thirds of the German territory, occupied by 29,000,000 of inhabitants. Its limits are, on the south, the Germanic provinces of Austria, and Switzerland; on the north, the Kingdom of Hanover, the two Grand Duchies of Mecklenburg, the Duchy of Limburg, and the Netherlands. The number of exhibitors entered in the Official Catalogue from these states of the Zollverein, including Hamburg, Hanover, Lübeck, Mecklenburg, and Oldenburg, is about 1,520; so that, after making the important deduction of Austria, not included in the Union, Germany is about equal to France in the number of exhibitors.

The raw materials exhibited by the Zollverein were of great variety and importance; especially those specimens connected with mining and metallurgy, in which arts the Germans have been, from a remote period, the tutors to all other nations. *Iron* and *steel* were exhibited in abundance, together with specimens of what is called *gas-iron*, in which, carbonic oxide being driven through the melted mass in the refinery, the carbon is more effectually removed than in the usual methods by charcoal or by puddling. The process originated in the necessities of the districts where this iron is produced. The lignite fuel not being favourable to the production of good iron, was distilled in close vessels, and the resulting gases were used to refine the iron. The

castings of Berlin iron were very numerous; and the trinkets, statuettes, fancy scrolls, and other works, maintained their former high reputation, which of late years has been somewhat tarnished by the inferior works offered for sale to travellers in Germany, at very high prices. The minute detail of some of these works excited surprise in those acquainted with the difficulty of producing such castings with the metals at our disposal. The process is certainly not fully understood by us: the great fluidity of the metal required in such minute castings is produced probably by the admixture of some substance such as phosphorus; although the nature and purity of the iron, the freedom of the fuel from sulphur, and the kind of casting-sand employed, are all largely concerned in the success of the process. Several varieties of *German steel* were also shown. This resembles the Indian wootz in character, and is made direct from the ore: the loss of iron amounts to between 20 and 30 per cent., and about 600 bushels of charcoal are required for every ton of metal. The finer varieties of the ore are selected for the manufacture: these are pounded, washed, mixed with charcoal, and placed in the furnace, which is excited by the cold blast. The ore, *stahl-stein*, or *stal ore*, commonly used for the purpose, is spathic iron, [see p. cxii.,] a crystalline carbonate, of considerable purity. The peroxide of manganese contained in the laminated varieties is supposed to be favourable to the conversion into steel. The stahl-stein is usually of a pale brown colour, which darkens by exposure: it is very abundant, and occurs in veins, often of enormous thickness, in Westphalia, Styria, and Biscay, in Spain. The ores of *zinc* were abundant; especially the calamine earths, or carbonates of zinc with oxide of iron, aluminous earths, and, in some cases, *cadmium*. The most extensive zinc-works in the world are in Silesia, which contributed numerous illustrations of its superiority in this branch of industry. Silesia also afforded a valuable lesson in the application of ores which were formerly considered as of no value. Some mines at Reichenstein had been abandoned for five centuries on account of their poverty, although the ore was known to be auriferous; the arsenical pyrites containing about 200 grains of gold in the ton. By a process adopted by Professor Plattner, of Freiberg, the ores are roasted in a reverberatory furnace, surmounted by a large condensing-chamber, in which the arsenic is deposited as it arises in fumes. Oxide of iron, a certain quantity of arsenic, and the gold, remain beneath. These are placed in a vessel, and a current of chlorine is transmitted through them: the gold and iron are attacked, and separated from the residue by solution in water, and the gold is precipitated by sulphuretted hydrogen.

Prussia had several rich displays of *amber*, a fossil resin of various extinct species of coniferous trees, allied to the firs and pines of the present age. It is obtained chiefly on the shores of the Baltic, between Konigsberg and Memel. According to Dr. Karl Thomas, a stratum of amber earth lies under a nearly horizontal stratum of alluvial sand and coal-bearing clay, on the coast. This has been explored where it rises above the level of the sea, and carbonized coniferous wood is found in it, with organic remains. The amber frequently encloses small insects, &c., and the exterior surface is often marked with the impression of branches and bark, and in one example the corolla of an unknown flower is enclosed. From the amber bed on the coast of Dirschkeim, which extends under the sea, no less than 800 lbs. were thrown up during a storm, on the 1st of January, 1848. A pound of amber sometimes produces 100 dollars (15*l.*). Amber, in its crude and manufactured state, was abundantly illustrated; the varieties in colour, transparency, and brilliant polish were very numerous. The manufactured articles in amber consisted chiefly of pipe mouth-pieces and cigar-holders, beads, bracelets, ear-ring drops, and breast-pins: there were also vases in yellow and white amber, chess-men, ladies' ornaments, paper-cutters, fruit-knives, &c.; but by far the most abundant demand for this curious substance seemed to be on the part of the tobacco-smokers.

The best-arranged and most complete collection of raw materials in the Zollverein was contributed by the little Duchy of Nassau, which is singularly rich and varied in mineral produce. "A large part of the country is covered with basalt, but beneath and amongst this are schists abounding with small mineral veins, and alternating with altered limestones and marble. Mines have been worked extensively in the upper part of the valley of the Lahn, where the principal mineral produce is rich copper ore. A little to the west are masses of iron ore, amongst which the *stahl-stein*, or sparry carbonate, is the most remarkable. There are also in many places

veins of rich argentiferous galena, formerly worked to much greater extent than at the present day. Some of the mines also contain nickel, cobalt, zinc, and manganese, in considerable quantities. Dillenburg may be regarded as the capital of the mining district of Nassau. The beds of lignite near Hachenburg, and elsewhere in the country, are very thick, and contain a large quantity of material; but hitherto they have not been economically worked, nor has the lignite been used to any extent compared with the large supply that exists." Specimens of nickel, in cubes, as it is brought to the market, were exhibited. The nickel is found in combination with sulphur, mixed with copper and iron pyrites: it is not separated by smelting, but by solution in acids. There were also specimens of German silver, composed of 8 copper, 3 nickel, $3\frac{1}{2}$ zinc; and the same with $6\frac{1}{2}$ zinc. Marble of different tints,—red, black, yellow, and grey,—but of irregular texture, was exhibited, worked up into a variety of ornamental forms.

The mineral contributions of Belgium were of interest. The hone-stones (silicates of alumina) obtained from the slaty rocks of the Luxembourg, are well known. Belgium is also rich in mill-stones, obtained from the grits of the older geological period; but they are not equal in quality to the French buhr-stones. Specimens of Namur coal were also exhibited: the area of supply of this coal includes nearly 6,000 acres in the province of Namur, and upwards of 100,000 in that of Liege. There were also specimens of the Hainault coal, which occupies a surface of 200,000 English acres, including bituminous and anthracitic varieties. "There are in all," says Professor Ansted, "114 different seams in the district, the greatest expansion of which, near Charleroi, is of great industrial interest. There are three distinct kinds of coal, viz. 1, the *upper* or *Henu* coal, which burns easily and rapidly, with much flame and smoke, and is adapted for steam boilers; 2, the *middle* or *bituminous* coal, well adapted for coking, and for the forge, and also for domestic purposes; and, 3, the *lower* or *anthracitic* coal,—friable, contains little bitumen, but burns with much heat, and very slowly. The workings for coal in the Mons district are carried on at considerable depth; the upper beds being 1,000 feet deep." Mueseler's safety-lamp, used in the Belgian mines, was also exhibited. In this modification of the Davy lamp, the flame is enclosed within a thick glass, covered by a metallic gauze, through which the air required for combustion descends, while the products of combustion ascend through a sheet-iron tube surmounting the flame. When clean, it gives more light than the Davy; but should the glass be broken, the "safety," of course, vanishes. The *iron* of Belgium is of good quality, and stands next to our own in commercial importance.

Among the rich and varied contributions of France, raw materials were not very conspicuous. The celebrated mill-stones of La Ferté-sous-Jouarre, in the valley of the Maine, were exhibited in a variety of forms. These stones are highly esteemed in France, England, and even in America: they are siliceous conglomerates, found in irregular blocks in an alluvial bed, and covered by a stratum of surface soil of variable depth. *Slates* from Rimogne and other places in the Ardennes were of fine colour and great hardness, the latter quality shown by the clear metallic sound which they emitted when struck. The *marbles* of Languedoc were very varied: the colours and texture were good; they were hard, and the slabs of large size—a combination of qualities not often exhibited. An interesting series of *asphaltic* works, and natural and artificial *bitumen*, and mosaic works united by asphaltic mastic, reminded the visitor that the use of asphalte in paving originated in France. The material is obtained from limestone occurring in several parts of France; but of late years large quantities have been found at Bastenne, in the south, near Orthez. The bitumen occurs in a bed from ten to fifteen feet thick, with occasional thick layers of shells: above and below it are sands. When fresh, it is easily cut, and is purified by boiling two or three times in a large quantity of water, when the sand subsides: after a few days' exposure to the air, it becomes too hard to be purified. It is laid down in the manner described in our article Asphaltum, p. 81. A machine was exhibited by M. Maehly, for extracting oil from *bituminous schist.* Sheet-iron retorts are placed horizontally in a reverberatory furnace, and heated to redness: the lumps of schist are spread out upon shelves of perforated sheet-iron, placed one above the other, so as to expose a large surface of schist to the heat: under these circumstances, a quantity of oil is disengaged, which is received and condensed in cold water, the yield being much greater than by the ordinary method of distillation. M. Moreau

exhibited a patent coal made from vegetable and herbaceous matter, fossils, &c.: it is said to burn without smoke or smell, to last longer and to give greater heat than charcoal. The inventor says:—"The substances mentioned are mixed with a third of their volume of coal in powder; the mixture is placed in conical metal tubes, and reduced in a heated oven. In an hour, solid pieces are produced by the fusion of the coal between the interstices of the mixture, and by compression: the inflamed gas maintains the oven at a temperature sufficient to carry on the operation. The heating power of this coal is increased by immersing the combustible matter as it comes from the oven in a solution of caustic potash. The sulphurous action of the product is destroyed by adding neutral metallic salts, where turf is the matter employed." One of the most valuable inventions on the subject of fuel in the whole Exhibition, was that indicated by the brief and modest entry in the Illustrated Catalogue, "No. 51, Berard and Co.: small purified coals and residue of the same, the produce of a system for purifying coals patented in France, England, Belgium, and Germany." The great importance of this invention may be less appreciated in England where good coal is abundant, but it is of value in places where coal containing much iron pyrites is what is called *sulphurous;* or where it exists in numerous small seams, and cannot be got out without a considerable admixture of slate and stony matter. The coal used on the Chemin de Fer du Nord was so sulphurous, that the locomotives were greatly injured by it: by using the purified coals a considerable saving was effected; the quantity of ash was also greatly reduced. The general principle of the apparatus employed is that of the *jigging machine* used in dressing ores. These, after being stamped in order to separate the stony matter, are agitated in water, and on being allowed to rest, the various portions become arranged according to their specific gravities. M. Berard's small case contained some of the washed coals and samples of very pure coke made from them: there was also a drawing and description of the machine.

The French colony of ALGIERS had some interesting contributions. There was crystallized *salt* from the salt Lake of Arzen, *iron* ore from Mount Filfilah, *grey copper* ores from the Mouzaie Mines, 2,000 tons of which were about to be sent to Swansea: there were also samples of *carbonate of copper* and *galena* of Oum Thebul, oxide of *antimony* and Taya *cinnabar, copper* mixed with *zinc* of Ain Barbar, *antimonial galena* of Djebel Cheggaia, magnetic *iron* of Saf Saf, oxides of *iron* from various parts, *white marble* and *lignite.*

The contributions of SWITZERLAND illustrated tolerably well the mineral wealth of this wonderful land. There were specimens of *slate, gypsum,* numerous varieties of *marbles, earthenware clay, iron* and *steel,*—the iron of Berne being celebrated for tenacity, malleability, and resistance to fire. The metals of Switzerland, viz. iron, copper, nickel, cobalt, argentiferous lead, and zinc, are not produced in sufficient quantity for home consumption. Salt and coal are also imported.

The PAPAL STATES contributed some beautiful specimens of natural alum from Tolfa near Rome.

The mineral wealth of TUSCANY is so great as to earn for that little state the title of the "Saxony of Italy." She contributed numerous specimens of minerals extracted from mines that are now in full work, and from others which are known to contain rich ores. Samples of excellent building stones and marbles represented abundant supplies at home: there were also beautiful specimens of *boracic acid,* contributed by the Count de Larderell, the inventor of the present method of extracting it, as described in our article BORON, p. 170. The pure crystals form, with oxide of lead, a very uniform glass, well adapted for making lenses for optical instruments. Some beautiful marbles were exhibited from the quarries of Seravazza and elsewhere: there was also a specimen of *granite* from the Isle of Elba, from which some remarkable blocks have been procured at different periods. The large columns in the Cathedral and Baptistery of Florence were cut from blocks in the mountains of Elba. The Grand Duke Cosmo I. caused a piece of granite from that island to be shaped into a large bowl 66 feet in circumference, for the garden of the Pitti Palace at Florence. There were also specimens of lithographic stone, and alabaster. Chalcedony, agates, the Arno pebble, &c. of various tints and lively colours, furnish materials for the manufacture of *pietre dure* works, in which flowers, fruits, animals, &c. are

represented in the natural colour of the stones. There were specimens of fossil flour and floating bricks made thereof. *Colouring earths* and *Tripoli earth* from Elba and other parts of Tuscany were exhibited: of these there are three qualities: those obtained from ferruginous and clayey sediments, such as the *yellow earth* and the *terra d'ombra* of Castel del Piano; others formed by subterranean waters infiltrating in the strata, and leaving behind particles of oxide of iron, manganese, and clay; thirdly, various ochres, abundant in the vicinity of the lodes. There were also specimens of *sulphur, rock-salt,* and *alum;* of *iron ore* from Elba; *copper, argentiferous lead, cinnabar,* and *quicksilver.* There were also samples of very good coal.

The industry of SARDINIA was very well represented: the mineral specimens included some *spathic iron ore* and rough and manufactured *slates,* one rough slate measuring 5½ feet square.

The collection from PORTUGAL was extremely rich in raw materials and produce, many of which were scarcely if at all known out of the country. There were numerous specimens of *limonite,* a hydrous oxide of *iron* occurring in abundance and affording excellent iron. There were also specimens of *copper, lead,* and *antimony* ores. *Lignites, anthracite,* and *coal* illustrated the sources of fuel possessed by this country. There were also *porcelain* and *fire-clays,* and *lithographic stone,* which was not generally known to exist in Portugal before its appearance in the Exhibition. A copious and splendid collection of *marbles* was contributed by the Museum of the Royal Academy of Lisbon: some of the specimens were of great beauty and singularity of veining: some of the colours were rose and white with stripes: there was also red marble with white veins; violet marble; rose marble with green veins; violet marble with black veins, &c.

MADEIRA and the WESTERN ISLANDS contributed specimens of *opal, lignite, limestone, stalactitic carbonate of lime:* also *dripstone* from Tercina, one of the Azores, valued as a filtering stone; it is very sonorous, and yields a peculiar tone when struck.

SPAIN was very remarkable for the abundance of her raw materials; and it was stated that the samples exhibited, numerous and well-arranged as they were, would convey but an imperfect idea of the vast mineral resources of this productive country. The commissioner for Spain, M. Ramon la Sagra, in his introductory remarks to the list of contributions given in the Official Illustrated Catalogue, says:—

Spain possesses in many portions of her territory enormous fields of pit-coal. The most productive and the most celebrated of these occur in the province of the Asturias, and among the interior faces of the mountains themselves. The price of Asturias pit-coal at the port of Gigon (the only point at which it can be shipped) is about 3 reals per quintal of 800 Castilian lbs. each. But at the pit mouth the price is fully one-third less; its cost on the coast being much enhanced by the difficulties of inland carriage. The coke that is manufactured from it in the open air fetches 3, 4, and sometimes even as much as 6 reals per quintal. The pit-coal raised in the Sierra and the Lagrao mines is chiefly exported. The coal dug in Mieres and at Leria is consumed in that country by the furnaces for smelting their iron, steel, &c. Several companies have been formed; some, for the improvement of the methods of mining; others, for the construction of common high roads and tramways for carrying this coal. The mining associations of the Valley of Santullan, in the province of Palençia, situate about two leagues from the grand route of Santander, and five leagues from the canal of Castile, are anxiously looking for the execution of those projected lines of railroad that are to connect Alen with Santander, and Madrid with Valladolid, as offering a cheap and enormous outlet for their very abundant supplies. The supplies of coal raised by the Polentina Leonesa Company in a very extensive district that is peculiarly rich in iron ore, of the province of Leon, will find a most profitable vent by the lines of railway communication now intended to be laid down. These beds of coal are very numerous, and of an average thickness of from two to three metres. The Spanish collection contains a sample of pit-coal from Guadita, in the province of Grenada; another of brown jet; and a third of polished jet from Oviedo. Out of this material small articles are manufactured, which are sold at moderate prices in the Asturias. The collection contains, moreover, some lignite from Guipuzcoa, much used in the mines of that country.

Spain also possesses almost every species of the metals which are the object of industrial labour. Among many others, gold, encrusted with quartz, has just been discovered in the province of Gerona. The various substances exhibited coming within the class of stones and earths, are but a very inadequate exponent of the riches, of an analogous description, that she really possesses. In this respect the soil of Spain is undoubtedly as rich as it is in metallic products. One cannot take a single step in this boldly-featured region without coming upon enormous masses of marble, serpentine, alabaster, puzzolanos, kaolins, hydraulic chalks, refractory freestones, plastic clays, and many other raw materials.

There is a tolerably rich collection of marbles, alabasters, clays, and serpentines, from different regions of Spain. In addition to this, a still more comprehensive collection has been transmitted from Madrid, including 87 specimens of the peculiar series of Cordova, of Grenada, of Almeria, of Leon, of the Asturias, Saragossa, Huelvas, and Guipuscoa.

Some of the beautiful marbles of Spain are very high priced, according to their respective qualities of

solidity and shading. The state of the roads and communications is such as to render almost impossible the transport of heavy dead weight material, and at once limits the employment of these marbles to the richer classes of each country, and so maintains high prices. Eight specimens are to be found in this collection from the Isle of Pines, in the near vicinity of Cuba; and in that locality marbles have long been found in great abundance, but without having yet been used in the rich Spanish colony in question, which absolutely imports others, notwithstanding, from Italy and the United States.

Sweden and Norway sent abundant illustrations of their excellent iron and steel; the purity of the former probably arising from the fine magnetic ore being smelted with charcoal. It is stated that as the manufacture of iron is of great importance to the prosperity of the country, it is carried on under the superintendence of a Central Board. Licences to manufacture certain quantities of iron annually are granted, and every furnace and iron forge pays an annual duty to the crown. The amount permitted to be manufactured is regulated according to the means of the iron-master to obtain the requisite supply of charcoal without public injury from its consumption. About 90,000 tons are made every year in Sweden, 70,000 of which are exported. There was a good collection of ores, and specimens of steel and of toughened iron, some of the specimens illustrating the quality of toughness and resistance to fracture. Chrome iron ores were also exhibited.

The raw materials of Russia were of great interest, especially those belonging to the mineral kingdom. A number of the imperial iron-foundries, which are conducted on a scale of great magnitude, sent specimens of the best productions of the Russian forges and furnaces. There were various specimens of *clay iron-stone, magnetic iron ore*, &c. According to M. Erman, the ore at Neviansk is procured at a short distance from the furnaces, where a shining mass of red iron-stone appears just at the surface of a bed of clay, the colour of which varies from green to yellow. This bed is cut by a seam of variegated limestone running in the direction of the Grand Uralian range, and in contact on either side with a somewhat loosely schistose serpentine. The smelting-houses here obtain a supply of ore from Nijny Tagilsk, also of a peculiar sort of iron-stone. It is distinguished by the remarkable crystalline structure of its gneiss. It requires a sharp roasting before going into the smelting furnace, otherwise it collects into lumps without being reduced, and layers of unsplit pine-wood are usually intermixed with it when roasting. These layers are continued alternating about every 3½ feet with the layers of ore, which are 7 feet thick, until they reach a height of 35 feet upon a surface of 2,500 square feet. A cruciform opening is left in the pile of wood for the passage of air, and the whole is well secured with a strong framing of timber. Whole forests of timber are set apart for this extravagant operation. In the production of the ordinary crude iron the Tagilsk and Neviansk ores are smelted together with an admixture of sand and ferruginous clay: but Neviansk offers the best material for cannon and balls, the magnetic iron-stone of Tagilsk furnishing metal too hard for such purposes.

The Russian *sheet* and *plate iron* was particularly admired. It is produced at the Imperial Iron Works of Nijne-Tourinsk in the following manner:—The rollers used are not formed in the lathe, but cast at once with the requisite smoothness and regularity in moulds rubbed over with graphite. While the plates are being rolled the edges are kept free from gaps by paring them with large shears. They are then placed on layers of from 10 to 20 on a moving bench, which passes them to and fro under a hammer of 40 poods weight: both sides are alternately exposed to its action, and a man carefully brushes off the scales that are continually produced on the surface. The parings are mixed with half their weight of charcoal, and converted into bar iron. Some fine specimens of steel were also exhibited from Zlataoust, the great centre of the iron and steel manufactures of Russia.

There was a variety of *copper* ores from the Imperial Bogoslovsky copper works; but the grand display of copper ore was in the form of the ornamental *malachite*, which was so abundantly displayed in furniture, vases, &c., as to give a peculiar character to the Russian department. A pair of malachite doors 14 feet 5 inches high and 7 feet wide was the most costly among objects exhibited in this material. Professor Ansted, in his notes to the Official Illustrated Catalogue, says that these doors "are built upon a framework of metal, the malachite being veneered in thin slices about ¼ inch thick. But the chief peculiarity of the

manufacture consists in the ingenious way in which the cut pieces of stone are adapted to each other so as to form a pleasing and appropriate pattern, and cemented by a very coarse cement made of fragments of the stone itself, and coloured in the same way. The magnitude of each piece of malachite is very inconsiderable, any single object being made up of hundreds, or even thousands of pieces cut into a fit shape. In this way a large proportion of the whole is absolutely lost; and as the finer pieces are valuable, the cost of material is thus very considerable in addition to the great labour. Some idea may be formed of the latter when it is stated that in addition to the labour of cutting and partly fitting the pieces, it occupied as many persons as could be employed on the doors (30 men) a full year to fit, finish, and polish them. The total quantity of labour employed was, however, much greater than would thus appear, since the work went on day and night without ceasing during the whole time, from the 1st May 1850 to the beginning of May 1851. The vases and chimney-piece of the same manufacture are hardly less valuable and magnificent than the doors, and the whole value of these goods is stated at nearly 18,000*l.*

The mighty chain of the Ural contributed specimens of *gold, silver,* and *platinum;* the latter substance, the heaviest in nature, being coined into money The Altai mountains also contributed *silver ores.* There were also beautiful vases of large size turned out of *jasper, quartz,* and other extremely hard rocks. The collection of *gems* and *precious stones,* variously arranged and mounted, also contributed to make the Russian collection one of great beauty, interest, and value.

Turkey sent specimens of native *sulphur* from Jerusalem; *iron ore* and *coal* from Mount Lebanon; *pipe-clay, rock-salt,* &c. Greece sent some beautiful specimens of *marble* from quarries whose names carry the mind back to the times when the Parthenon was in its glory. There were specimens of *steatite* or *soap-earth* from the island of Kimaulo, where it exists in large quantity, and is used as a substitute for soap: *mill-stones* from Milo, composed of pure quartz, a very small quantity of clay, and potash to about 1 per cent.: these stones are used in flour-mills in Greece, and upwards of 200,000 are exported annually. Also *sulphur* from Milo; *emery* from Naxos; *puzzolana,* a volcanic ash, forming with lime a valuable hydraulic mortar; *meerschaum,* or froth of the sea, an earthy and silicious carbonate of magnesia, found in the hills near Thebes, and much used for making pipe-bowls.

Egypt contributed some beautiful specimens of what is called *oriental alabaster* of rich tint and peculiar veining: it is not, however, an alabaster, which is a *sulphate* of lime, but a peculiar marble or *carbonate* of lime. Specimens of *trona,* sesqui-carbonate of soda, from some lakes situated to the west of the Nile were interesting.

The minerals from Tunis were not numerous, but we may notice an *alabaster* used for the more delicate arabesque ornaments.

China was represented by several valuable collections belonging to English residents or traders. There was the celebrated *kaolin,* and a complete collection of the various materials used in the manufacture of porcelain; also a large collection of colours used in painting porcelain. There were specimens of *coal,* an excellent *hone-stone,* and some common fine *clays.*

We now take leave of the mineral raw materials of the Great Exhibition: their extent, variety, and importance, will justify the length of this notice, especially when it is considered that the mineral kingdom forms the basis of the industrial arts, and also that we have brought forward several valuable and remarkable processes which are quite in place in the present work. Our notice of the other great sections of the Exhibition must be more concise. Were space afforded us, it would be easy to carry out the present Essay, so as to form a complete and extended record of the state of the useful arts in the year in which a festival was celebrated to industry, such as had never occurred before, and will probably not occur again.

Section XI.—Vegetable Substances Exhibited.

Surveying the Great Exhibition throughout its length and breadth, with the sole view to the vegetable productions contained therein, it was impossible to avoid being deeply impressed with the beauty, variety, utility, and wondrous extent of this kingdom of nature as there enlisted in

the service of man. The first impression was doubtless that of beauty. The living trees and flowers in the transept; the exquisite imitations of the latter, fabricated from vegetable substances, wreathing with life-like grace pillar and pedestal; the variety of beautiful woods, which in the form of ornamental furniture and elaborate carving enriched the whole extent of the nave, and gave interest to many of its side courts; the fossil timber, which, as taken from the Irish bogs, was converted to purposes of ornament; the draperies, muslins, chintzes, damasks, &c., that clothed their allotted departments; the rich and extraordinary display of lace, that arrested so many visitors to the galleries; the brilliancy of vegetable dyes, which lighted up so large a proportion of the objects displayed; the graceful forms to which grasses and straw were turned in bonnets, and baskets, and especially in the straw-flowers, plumes, and wreaths of Switzerland; these and many other beautiful objects wholly derived from the vegetable world. gratified the eye, and appealed to the manifold tastes of millions.

But the variety of these objects was not less remarkable than their beauty. This became more and more manifest after repeated visits, and in proportion to the diligent exploration of the side courts and galleries of the wondrous edifice. For instance, beautiful as were the varieties of timber converted to the use of the cabinet-maker, and displayed in massive and imposing, or in light and elegant forms throughout the more conspicuous parts of the building, yet they gave but a faint idea of the variety of English and foreign woods adapted to such purposes, in comparison with that afforded by the numerous horizontal and transverse sections, and by the collection of other specimens of wood in the form of volumes, occupying remoter parts of the edifice. These beautifully polished slabs, each bearing on the back its proper title, might easily have been mistaken for a real library by such as gave them only a passing glance, the fine dark colour of red cedar, ebony, mahogany, pheasant-wood, rosewood, &c., representing the more sombre bindings, while the light hues of satin-wood, lime, willow, canary wood, hickory, locust, box-wood, &c., shone out as if the volumes were freshly bound in "calf." But on a nearer view the excellence of the idea was recognised, which thus presented in a compact and pleasing form, numerous specimens of wood, many of which were scarcely known as ornamental; thus proving that the resources of the vegetable world are in this respect far greater than is commonly supposed, and that they have as yet been rendered available only to a very limited extent. Again; extensive and pleasing to the eye as were the textile manufactures of the Great Exhibition, where the vegetable substances, cotton and flax, were wrought into an immense variety of beautiful fabrics, and where the processes of the manufacture were also gone through before the eyes of the visitor; yet they gave but a feeble notion of the treasures which the vegetable kingdom has yet in store for the reward of manufacturing skill. The collections of raw materials in the several departments supplied this deficiency, and displayed many substances which were perfectly new to the majority of beholders, and which yet bore the marks, not to be mistaken by experienced men, of applicability to the purposes of the useful arts. Thus in the Indian department, a quantity of fibrous material was brought together, which excited great interest as presenting valuable substitutes for hemp and flax; manufactured articles were there likewise, bearing the titles, "cloth from native fibres," "cloth from Papyrus bark," "cloth from the bark of the Paper Mulberry," "cloth from plantain fibre," "canvass from Wackoonar fibre," "pine-apple flax rope," &c., all testifying to the abundance of these fibrous materials, and, at the same time, to the smallness of our present knowledge. In the Canadian department, likewise, among other interesting vegetable substances, was a specimen of what has been called silk-cotton, sent from Montreal, the produce of a plant called by the Canadians the Cottonière, and growing freely all over the country. It grows to the height of two or three feet, but when about six or eight inches high it is often eaten as asparagus, and has hence been sometimes erroneously called wild asparagus. The fruit of this plant is a pod, three or four inches in length, filled with silky seeds. Some of these pods, with an abundance of silk bursting from them, were exhibited in the same case with specimens of felt and cloth manufactured from this beautiful material. The exhibitor recommends this substance as one which can be used to great advantage by the hat-manufacturers of Great Britain. There was also an interesting group of fibrous substances from Ceylon. Bundles of long glossy fibres hung from the wall of the

compartment, and were marked as plantain, pine-apple, aloe, cardamum, hibiscus, and some other less familiar names. In the Spanish department, again, was a specimen of manufacture in pine-apple fibre which created general surprise; being none other than a richly worked white muslin robe, fine and beautiful in texture as muslin obtained from cotton.

The variety of the vegetable substances displayed in this great magazine of arts, led the mind, as a necessary consequence, to the uses to which they are put; and these are indeed manifold. Not to speak of the timber used in the framework of the glassy roof and walls, and the flooring of the palace itself, with the whole array of pillars, pedestals, tents, stalls, benches, tables, &c. placed thereon; though these were sufficiently illustrative of the uses of the ordinary kinds of timber; there were beautiful objects in all the departments to show the endless purposes to which the finer woods are devoted, in musical instruments, cabinets, carved works, mediæval and other furniture, inlaid flooring, &c. &c. There was also proof in the department of machinery and of carriages, and especially among the agricultural implements, that we owe to the vegetable kingdom a large proportion of the convenience and comfort afforded by our modes of transit, and by our machinery and implements of labour. The employment of timber, however, was only a very small part of the use of vegetable substances as shown in this instance. The root, the bark, the leaves, buds, flowers, and fruit of trees and shrubs, were shown in their several applications, and even the ordinary edible vegetables were represented with great accuracy by waxen models. Bundles of woody fibre, and packages of dried herbs, in the valuable collections of chemicals, told, by their labels, of esteemed medicines, whose scientific names and properties are familiar enough, but whose appearance in the unmanufactured state was perhaps a novelty to thousands. Other dried leaves universally known and appreciated, represented the indispensable beverage, tea, in all its varieties, not only for ordinary use, but for medicinal purposes. Physic teas, could we trust Chinese authorities on this point, possess the valuable properties of removing hoarseness, indigestion, fevers, rheumatisms, and inflammatory diseases of all kinds, as well as of clearing the mind, quieting troubled feelings, brightening the vision, and enlivening the spirits! But the well-known refreshing and invigorating qualities of ordinary tea may suffice to maintain the reputation of this valuable shrub. Other dried leaves, of larger growth, represented another great branch of trade, which supplies the population of this and other countries with tobacco. Connoisseurs in this article might there view it in all its forms, from the simple roll of tobacco in the Canadian department, weighing 55 lbs., to the choice collection of cigars in the Spanish department marked *Regalia de la Reina*. These and numerous other specimens of the uses of the *leaf*, in trees, directed attention also to the value of the bark, in tanning, and for medicinal purposes; of the flower, whose petals and stamens have sometimes commercial and medicinal uses; and especially of the fruit or seed, which supplies the greatest proportion of the food of mankind, and of many of the lower animals also. The collections of grain in the Exhibition were large and remarkable, while the display of fruits, dry, and in the state of preserves, was most tempting. Here were grapes, figs, nuts, and almonds with all kinds of agreeable looking sweetmeats; apricot pulp and sugared pistacio nuts from Damascus; various preserves of dates and tamarinds from Egypt; sweetmeats of grape-juice from Angora; figs from Smyrna; scented sugar from Adrianople, &c.; while the fruits of Spain and Portugal, of France, and of our own country were there in great profusion, preserved in a variety of ways. Berries and nuts of all descriptions were present, from the valuable coffee-berry to the "pine nuts from fir-cones of Mount Lebanon." Sometimes the grain exhibited had some peculiar label to excite either interest or amusement. Thus there were ears of Indian corn "grown by fugitive slaves, settled in Dawn, Canada West, equal to any produced in the Southern States;" and in the United States department we were coolly requested to admire some fine ears of Indian corn, "made" by James Merriwether.

If beauty, variety, and utility marked the vegetable treasures of the Great Exhibition, it will be confessed on all hands that they were not wanting in extent. Indeed, the great space devoted to examples of vegetable productions, merely as such, while it afforded delight to the botanist, seemed to fatigue many an ordinary visitor. "I see nothing remarkable here," was

the speech which met our ears, on one occasion, while we were studying that deeply interesting collection of the vegetable productions of Scotland, made by the Messrs. Lawson of Edinburgh. This, from intelligent lips, was truly astonishing, for there has seldom been a more attractive and instructive collection than the one in question. The groups of sea-weed and of skeleton leaves in the same gallery attracted universal admiration, partly, perhaps, on account of the fanciful manner in which they were arranged; but this really scientific collection, where the whole history of plants might be traced, their relationships ascertained, and their uses discovered, was disregarded by numbers who were little aware of their loss. The same may be said of the valuable specimens of raw produce from Liverpool, illustrating the import trade of that port, and also of several other important collections appealing more to the mind than to the eye.

It is worthy of notice, that in the Great Exhibition, even independently of a few able and judicious attempts at the classification of plants, there have been brought together as if by accident, specimens of the most remarkable tribes of the vegetable world, from the lowest and most rudimentary forms, to the highest and most perfect. The three great divisions called Acrogens, Endogens, and Exogens, which include all vegetable nature, had each numerous and appropriate representatives there. The first, which comprises cellular, flowerless plants, contains the lowest and most diminutive forms. Some of these are with difficulty recognised as belonging to the vegetable kingdom; indeed, by some naturalists, they are still ranked among infusory animals, being microscopic atoms, invested with siliceous cases, and occurring in such vast multitudes as to form in their decay a kind of powder or earth. This powder is in some cases used as meal, and eaten by the peasantry in time of dearth. It is the Berg-mehl of Sweden. Its ordinary use, however, is that of a polishing powder, and as such it appeared in the Exhibition. Other cellular plants of a higher kind are sea-weeds and lichens, of which there were not only collections to please the eye, but specimens with their manufactured results, several kinds of sea-weed being useful for the kelp, iodine, &c. obtained from them, while the lichens afford dyes. Thus from Glasgow, Galway, Donegal, Leeds, Spitalfields, Manchester, Huddersfield, &c., were sent various products obtained from sea-weed and from lichens. The archil, litmus, and cudbear of commerce, obtained from lichens, afford valuable red and blue dyes. Specimens of worsted yarn, and of woven fabrics and leather, dyed or printed with archil and cudbear, illustrated the nature of these dyes. Lichens spread their slender crusts over the trees and stones of tropical as well as of cold countries, a certain amount of moisture being, apparently, all that is needed for their well-being. Thus the finest and largest supply at the Great Exhibition came from islands off the African Coast, and were marked as "Wood-orchilla from Mozambique," "Rocks-orchilla from Cape Verde Islands," "Bis-wood-orchilla from St. Thomas's," &c. &c. A few of the lichens yield nutriment, especially the species known as Iceland moss; among the sea-weeds, also, are several having the same reputation. The gelatinous substance obtained from them, is of the same description as that of which the edible birds'-nests are made. These nests are most abundant in the Philippine Islands, and also in some parts of India. They are in high request among Chinese gourmands, and are imported at considerable cost. The price of a cargo is occasionally immense, and a story is told of an English captain having thrown overboard a sufficient quantity to have made the fortune of all his family.[1] In the Exhibition these nests were arranged on rock-work, to represent their natural situation. They were also placed in large china bowls, with a paper annexed to them, purporting to be a recipe for making "bird's-nest soup." Their beautiful filmy appearance, as they hung from their mimic rocks, made them very attractive objects to the visitors of the Chinese department. The highest forms among flowerless plants are ferns, which were

(1) The weed which composes this article of commerce is *Sphærococcus cartilagineus var. setaceus aq.* It is eaten by the bird (*Hirundo esculenta*) which builds the nests in question, and is used in their preparation. The swallow eats the fresh weeds and permits them to soften for some time in its stomach, then throws up the mass in the form of a jelly, and applies it to building purposes. These nests are subsequently smeared over with dirt and feathers, and are conveyed in their raw state to China, where they are cleansed in immense warehouses built for the purpose, and then exposed to sale. These nests, therefore, consist of little more than the softened weed, and their effects are no other than those of a fine jelly. In their preparation as food, a number of fine stimulants are generally added, and they occupy the first rank among relishes at the tables of the Chinese. The Japanese had long ago discovered that these costly nests are nothing more than softened sea-weed, and now prepare the substance itself in an artist-like manner. This weed is to be found in large quantities on the western and northern coasts of Great Britain.

represented in the Exhibition by living plants in Ward's cases; but these gave a very inadequate idea of ferns as they exist in tropical countries. We had hoped to see fronds and portions of the stem of the tree-ferns of Jamaica, some of which grow to a majestic height. Doubtless the small value of ferns in an economical sense was the cause of the omission.

Proceeding to the next division of the vegetable world—endogens—which comprise grasses, palms, orchids, lilies, &c., we find that the grasses, especially the valuable portion called cereals, were abundantly illustrated in nearly every department of the Exhibition. Canada sent numerous barrels of spring and fall wheat, barrels of barley, oats, and flour. Australia sent fine samples of wheat, one weighing 64 lbs. per bushel, illustrating the high character and excellence of the wheat which comes from our South Australian colonies, and which now takes the lead in the markets of this country. Casks of white wheat, velvet wheat, and flour of fine quality, appeared among the productions of Van Diemen's Land. The United States of America had many fine samples of wheat and of Indian corn. The latter was largely displayed in the ear, and above it were hung specimens of the excellent brooms and brushes which are made from its stems. Specimens of flour and farina from this plant, as well as starch obtained from it, were present. India sent samples of wheat, as well as of rice in all stages and rice-straw. Ceylon sent wheat and maize. Seven or eight distinct companies and individuals sent specimens of different kinds of flour, from Austrian and Hungarian wheat. Belgium also made a goodly display, her samples from East and West Flanders, Brabant, Namur, Luxembourg, &c. being worthy of notice. Portugal had numerous and fine samples. France and her colony of Algeria, Denmark, Russia, and her dependencies, sent grain—the last-named in large quantities and so arranged as to make a very effective display with other agricultural produce. Malta and the Cape of Good Hope sent wheat, flour, and maize. The famous white wheat of the Asturias, of Ciudad Real, Segovia, &c., drew attention to the Spanish department. Turkey sent samples from Salonicus, Damascus, Koniah, Adrianople, Tripoli, &c., with samples of pounded wheat for making *pilauf*. Upper and Lower Egypt sent wheat, Indian corn, and barley. Tunis had various samples of wheat under strange-looking names, as Hemira, Azyzy, Nigida, Sbihy, and Mahmoody. The corporation of millers from the Grand Duchy of Posen sent millet, grits, and oatmeal. Bavaria sent wheat, wheaten grits, bran, pollard, rye, barley, &c.: the Central Board of Agriculture for the Grand Duchy of Hesse Darmstadt also contributed samples of grain and agricultural produce. England, Scotland, and Ireland sent numerous samples of wheat, barley, rye, and oats, among which were samples of grain grown on the royal farm at Windsor, and exhibited by H. R. H. Prince Albert.[1] Thus importance was attached to corn of all kinds, corresponding in some degree with its immense value to men and animals. Nor were the grasses used for fodder overlooked. Dried, and arranged in an admirable manner, these formed part of the interesting Scottish and other collections already alluded to. Other varieties used in ornamental work were seen as manufactured in characteristic and pleasing forms throughout the Exhibition. Very interesting also were the specimens of giant grasses of other climes. The sugar-canes in the Egyptian department, and the specimens of rattans, bamboos, &c. from Labuan, brought to mind the noble growth and valuable uses of tropical vegetation. The bamboo is applied to a variety of uses, as baskets, flutes, fans, &c.; and we also found a "bamboo hackery," and a "bamboo undershirt." The latter most extraordinary garment, which was in the Chinese department, formed a coarse network, the small stems of bamboo being threaded in short lengths, and the shirt netted in a rude manner. The grass oil, "lemon-grass siri oil," in the Indian collection, represented the aromatic oils distilled from fragrant canes, one of which—*Andropogon calamus aromaticus*—is considered to be the sweet cane mentioned in Scripture. Sedges were represented by the mats and cordage sent from the Indian Archipelago, and by our native plant, the cotton-grass, whose silky tufts have been woven by a Scottish exhibitor into a kind of cloth. Palms, in their multiform uses, were represented by the preserved fruit of the Doum palm, from Egypt; by strings of fancy palm-nut beads, made out of burnt

(1) The important effects of *hybridizing* were also distinctly shown at the Great Exhibition. By this plan it was seen that cultivators may greatly alter the character of corn; so that, ultimately, there is no reason to doubt that the same improvements may be made in cereal crops, by crossing the varieties of corn, as in animals, by crossing various breeds.

kernels, as worn around the waist and neck by females of the better class in Western Africa, and by specimens of fruit, kernels, oil, and kernel-oil soap, from the same country, (which also sent the ropes of vegetable fibre used by the natives in climbing the naked trunks of palms;) by clusters of dates from Madeira; by various baskets, fans, artificial flowers, &c., constructed of the leaf-stalks and leaves of palms, the more beautiful being those from the Seychelle Islands; by articles in vegetable ivory, which is the stony albumen of the seed of a palm; by paper, pasteboard, cables, ropes, matting, cordage, rugs, brooms, &c., fabricated from various palms, chiefly the cocoa-nut palm, which also supplies the widely-employed stuffing for mattresses, so valuable in hospitals, prisons, or for private use. The coir, or fibre of the cocoa-nut, thus employed, is much cheaper and more cleanly than horsehair, and is far more elastic and durable than wool, flock, or any other material. Of the numerous articles of food furnished by these invaluable trees, there were not many specimens: a few preserves of dates, and some sago-cakes from the Moluccas, used as sea-biscuits, served to recal this use of the palms. The Fine Arts Court contained three ingenious and elaborate models, constructed of the pith of the common rush. The lily tribe was represented by a plant of great importance in our manufactures, but which is usually mistaken for a kind of flax, and is called New Zealand flax, though, in fact, a liliaceous plant. Pine-apple, agave, and banana, all yielded fibrous material for muslins and other manufactures; while orchids yielded vanilla and salep. In these, and doubtless in many other cases which escaped our notice, endogenous plants were well and abundantly represented in the Great Exhibition.

Ascending to the highest and most extensive division of vegetable nature, the exogens, we found collected from various tribes all the forest-trees that are familiarly known, and some that as yet appear as strangers, worthily represented in the Great Exhibition. Scotland sent varieties of larch, native Scotch pine, weeping birch, &c. Ireland made a goodly display of bog-oak, bog-yew, and other fancy woods. England had her sturdy oak and other native woods, variously displayed. India furnished a most extensive collection of woods, with scarcely a recognisable name to ordinary eyes, except mahogany and teak. Conspicuous among these were immense circular slabs of Lingoa wood, obtained by taking advantage of the spurs which project from the trunk. Ceylon sent ebony, manufactured into a beautiful table and chairs, the former richly inlaid with fifty different Cingalese woods, thus showing, in a small compass, the vegetable treasures of that island. Canada exhibited numerous planks of pine, spruce, tamarack, maple, basswood, ash, birch, red rock-elm, butternut, black walnut, white oak, and ironwood; the black walnut being also employed for bedsteads, chairs, &c. in a way which is likely to make it popular. A set of chairs in this material, sent from Quebec, and curiously worked in moose-hair by the squaws of Larrette, attracted much notice. Van Diemen's Land sent "blue gum" and "stringy bark" timber; the former celebrated for its vast dimensions, and for a durability which is said to equal that of the oak for ship-building purposes. Also squared logs and slabs of sassafras, myrtle, and muskwood of Tasmania. The myrtle of Van Diemen's Land composes dense forests of many miles, the trees often attaining a girth of from thirty to forty feet, with a proportionate elevation. The wood, which is of a fresh pink colour when newly hewn, is often beautifully veined and watered. Muskwood is also variously veined and dotted upon a brown ground. Both these woods are admirably fitted for cabinet-work and picture-frames, while sassafras-wood is well adapted for the inside work in houses. Musk and myrtle-wood picture-frames, with various other articles in the same materials, and in dog-wood, iron-wood, Huon pine, celery-topped pine, and rosewood or zebra-wood of Tasmania, enlivened this very interesting department. The United States sent her sweet gum-wood, Palmetto cedar, oak, and various forest and other woods. Russia sent beech, walnut, &c. The States of the Zollverein sent their collections of specimens of native growth, as did Spain and Portugal. The latter country exhibited native woods of pine, plum, filbert, olive, chestnut, elm, mulberry, beech, ash, cherry, cypress, cork, holm, poplar, oak, white acacia, walnut, box, &c. Western Africa sent teak; the Cape of Good Hope, boxes of specimens of Cape woods, in the bark, rough, and polished. Some of these were from a Moravian missionary settlement, which also exhibited various specimens of industrial art. Egypt sent clubs of ebony, samples of alizier wood, sycamore, and Doum palm,

the trunk of a date-tree, and specimens of sweet palm, acacia, azedarak, and liquorice-wood. Thus from all nations came valuable mementos of the timber, fruit, or other trees for which they are distinguished; and it needed but a moderate acquaintance with botanical science mentally to sketch the features of each country from the character of the vegetable products exhibited. The numerous uses of the bark of trees were made conspicuous in the Exhibition; and that most useful bark of a species of oak, which is familiar to us as cork, was there shown to be capable of conversion into the lightest hats that were ever made, and also into modelled pictures of castles, &c. The colour and structure of the cork admirably represented the time-worn appearance of old buildings. Berlin sent some of these cork pictures; our own Fine Arts Court also displayed a group of horses carved in cork, and an ornamental frame-work in the same material. The various uses of bark in dyeing and tanning were indicated by the large collection sent by the London druggists, as well as by an immense number of specimens scattered throughout the several departments of the Exhibition, many of which must have excited the interest and curiosity of our manufacturers by their novelty, and by the strange names attached to them.

Among the lower tribes of exogenous plants are some that found representatives in the Exhibition, although the general character of the particular group would not have led us to look for any of its members among the useful products there. Thus, the nettle tribe furnished hemp, and the so-called China-grass, which has of late years been so much valued in the manufacture of linen. Hemp was fully represented by the beautiful display of cordage and sailcloth in the Exhibition; while the stalk, seed, and capsule of China-grass were shown, along with the fibre in all its stages, bleached, softened, dyed, spun, and woven into linen. The spurges gave both the milky juice that forms India-rubber, and also the oils, which, as croton and castor oil, are so serviceable in medicine. They furnished also a vegetable tallow, much valued in China. India-rubber was largely displayed by the United States and by Great Britain, and if the India-rubber trophy of the former was deemed unsightly in the prominent position assigned to it in the nave, it had at least the merit of presenting some valuable adaptations of that useful material. A relation of the pretty mezereon of our gardens gave the beautiful fibrous tissue known as lace-bark. The lavender and other herbs yielded fragrant volatile oils; the fox-glove, nightshade, and tobacco, deadly poisons; the gentians, valuable tonics. Olive oil, and the oil called shea-butter, the produce of an African plant, were exhibited. So likewise was gutta percha, that valuable exudation from a plant related to the last named. Among the higher tribes, the composite plants gave dyes, food, and medicine. From the distance of Sparta and Moldavia came safflower, which furnishes rouge; and from Russia and other quarters came chicory, the recognised adulterant of coffee. From Ceylon, Trinidad, and various other places, came also coffee itself, that valuable member of the madder tribe, far more to be prized than the dyes for which the same tribe is celebrated. Among the curiosities connected with coffee in the Exhibition were specimens of essence of coffee, prepared by a peculiar machine, and a preparation of the leaves of the coffee plant for use as a beverage tea. Also a series of interesting models from Ceylon of coffee stores, drying platforms, machinery for removing the outer and inner skin, and coffee-curing apparatus. The umbelliferous plants furnished many valuable roots; myrtles appeared as forest trees; roses gave delicious attars; pulse yielded food, dyeing and tanning materials, gums and balsams. Beans, peas, and other leguminous products valuable as food, were abundantly shown in our own and many foreign departments. Of dyeing materials—from Trinidad came logwood, from South America Brazil-wood, from India, Egypt, Tunis, &c. came indigo. From all quarters came the gums and resins, the balsams and varnishes which are obtained from the same tribe. Not far from these, another and a smaller group sent a product which at the present time detains the serious attention of practical men, on account of the new promise of advantage held forth to our country in its culture under improved methods and prospects. This product is flax, of which a most interesting display was made at the Exhibition, as well of the raw product as of the finished material obtained from it. Beautiful yarns and rovings of flax, sewing thread of a superior quality manufactured from flax and China-grass, and all the varieties of flax cotton, flax flannel, flax velvet, and other

novel materials, introduced under Claussen's patent,[1] [See FLAX,] attracted attention, not less than the magnificent display of Irish and English damasks, some of which were manufactured for distinguished personages, and were evidently our highest efforts at that species of manufacturing art. Linen-cambric dresses and printed muslins, with the prizes they had gained for their beauty, were also exhibited. Many of the foreign departments also exhibited linen damask, and other products of flax in great beauty, but the article of lace was the most attractive. Perhaps there never was so exquisite a display of this material before. While Brussels maintained its old celebrity, and France gave good proof of the perfection of its manufacture, and while Russia, the Zollverein, Spain and Portugal, Switzerland, Malta, and even Denmark, Ceylon, and Van Diemen's Land, sent specimens of lace, England and Ireland had still reason to be proud of their own numerous and excellent productions.

The vine tribe was illustrated at the Exhibition by dried fruits, of which some of the finest, as might be expected, were from Greece. The orange tribe brought fruits and perfumes, as "orange-flower water from Scio, Damascus, and Tripoli;" while its blossom was successfully and profusely copied by the artificial flower maker. Camellias and tea-plants, the one for the blossom, the other for the far-famed leaf, were also in request. The collection of teas was large, and exhibited much variety. India brought numerous specimens of Assam teas to compete with those of China. The mallow tribe was brought to remembrance in this great assemblage of vegetable substances by the valuable cotton plant, which it includes, and which is of more importance to this country, in a commercial point of view, than any other foreign product. The food-section of the cruciferous tribe, though not actually exhibited, was so admirably represented by waxen models in the Lawson collection, that discussion frequently arose as to whether the turnips, radishes, &c., under those glass-cases, were real or artificial. The poppy tribe was represented by opium; the water-lily tribe by the numerous fanciful imitations of the flowers and leaves, especially of the gigantic species recently become known to us, the *Victoria Regia*, of which one of the most elegant representations was that which gave the leaf as a silver coffee-tray, and the bud as a handle to the same.

In addition to these and other examples, too numerous to mention, of plants, whose beauties or uses had brought them under notice at the World's Exhibition, there were also groups of dried plants, exhibited either on account of the interest attaching to the locality whence they came, or on account of a skilful preservation of their natural colours, or of some peculiarity in the mode of drying. Thus, in a case marked "Specimens of dried flowers from Mount Hebron," were a Star of Bethlehem from the Valley of Hinnom, a violet from Nablous or Shechem, oat-ears from Bethlehem, and a poppy from Cana of Galilee. Near at hand also were paper-folders and an inkstand made from the olive-trees of Jerusalem. Prussia sent picturesque groups of dried Alpine plants, and from Denmark and other quarters came similar collections. Among our own contributions in this way, the most successful was that in which the flowers were not crushed, but preserved in their natural form. The blossoms only, each in a separate cell, were ranged so as to be out of the reach of pressure, while they retained nearly their usual form and colour.

Taken as a whole, the vegetable department of the Great Exhibition was of a character to yield much instruction and delight, and to enhance in no small degree the feeling of regret experienced by all intelligent minds at the breaking up and dispersion of the treasures of the Crystal Palace.

(1) It appears that the cottonising of flax is not a new idea. In the first volume of the Transactions of the Society of Arts, (1783, is a communication from Lady Moira, accompanied by "specimens of cloth made from the refuse of flax and backings of tow, according to the process practised by her ladyship, 1775." Referring to these specimens, her ladyship says:—"I have no reason to be vain of the samples I have sent you: they merely show that the material of flax-cotton, in able hands, will bear manufacturing, though it is my ill fortune to have it discredited by the artisans who work for me. I had in Dublin, with great difficulty, a gown wove for myself, and three waistcoats; but had not the person who employed a weaver for me particularly wished to oblige me, I could not have got it accomplished; and the getting spun an ounce of this cotton in Dublin I found impracticable: the absurd alarm that it might injure the trade of foreign cotton had gained ground, and the spinners—for what reason I cannot comprehend—declared themselves such bitter enemies to my scheme that they would not spin for me." The method of preparing the flax is thus noticed:—"I tried soap-boilers' lye with very good success, scowering it afterwards, to take off any bad effects of the lime used therein . . . . I have boiled some in a mixture of lime-water and salt: this had a harshness in it that more resembles the crispness of cotton; but the scowering of it would certainly deprive it of that quality."

Section XII.—Animal Substances Exhibited.

The lower forms of animal life were scantily represented in the Great Exhibition, for few of them, comparatively, are available in the useful arts. There is, however, a remarkable exception in the case of Sponge; and this beautiful and useful article (sometimes ranked among vegetable substances) was there displayed in great perfection. There were sponges from the shores of the Bahamas, from Greece, Tunis, Turkey, and other countries; some coarse, and of enormous size, others extremely fine in their texture and quality. The tenacity with which these substances adhere to rocks, stones, or other submerged objects was illustrated by a specimen of a fine sponge firmly attached to a brown unglazed jug, which by some accident had become deposited in a part of the sea, near the Island of Rhodes, favourable to the growth of sponges. There were also fine and valuable specimens of Coral, which is the stony axis or skeleton of minute polyps, living together in inseparable union, and producing branchlike formations. The finest corals are brought from the southern shores of the Mediterranean; and one of our London importers and manufacturers made a goodly display of bracelets, cameos, necklaces, &c., with a figure of Bacchus carved in the finest coral; also a branch of natural rough coral, of great size and value. Specimens of unmanufactured coral were sent from the Cape of Good Hope and from Algeria, while necklaces came from Tuscany, and various spoons and other articles, manufactured in coral, were found among the rich and curious products of Turkey.

Passing from the lowest forms of animal life to a rather higher structure, we come to worms and leeches; and although the latter were not actually exhibited, yet their value was proclaimed by the efforts of our own country and of Russia to produce a mechanical leech, which shall perform the important office of the living one, with equal effect. These contrivances are doubtless valuable on ship-board, or in situations where the natural leech cannot be obtained. A most important position must be given to *insects*, as it respects the Great Exhibition; for to their labours are we indebted for all those rich materials in silk, satins and velvet, which adorned the various departments, and for those interesting collections of raw silk of various qualities made by our own importers, and by contributors from China, India, France, Austria, British Guiana, Ionian Islands, Malta, Madeira, Portugal, &c. The weaving of silk into cloth was common among the Chinese, we are told, from a very early period; so that silk, satin, or damask, was the ordinary dress of males as well as females in China, at a time when these materials were unknown, or very rare, elsewhere. The introduction of this beautiful substance into the different countries of Europe, and the care bestowed on the culture of the worm which produces it, have enabled many other nations to produce silk and silken goods of very fine quality, so as to vie with, and even surpass, the produce of the native country of the silkworm. Thus, although, at the Exhibition, the Chinese raw silk was worthily represented by Yun-kee, of Shang-hae, yet there were beautiful examples from France, Italy, Turkey, and India, which in many instances proved superior modes of culture. There were also large collections of cocoons, of great size, and models illustrative of the mode of rearing the worms, the accommodation provided for them when spinning, the silk-winding apparatus, &c. There were also examples in specimens of British-grown silk, showing that it is quite possible, though doubtless not profitable, to overcome the disadvantages of climate sufficiently to produce silk of much excellence in our own country. Silk-looms and machinery were likewise at hand, and the spinning of silk went on before the eyes of the visitors. The manufactured goods in this material were of extraordinary richness and beauty: the damasks, brocades, velvets, satins, silks, ribbons, &c., clothing many foreign departments as well as our own with splendour. Some of these were collected in a handsome silk trophy, in the nave. In some cases, as in the Indian, Turkish, and Tunisian departments, where gold and silver embroidery were plentifully bestowed on these rich fabrics, the effect was brilliant in the extreme. Some of this brilliancy was again due to insects, in the employment of the glittering wing-cases of Indian beetles in various gold embroideries, among which they sparkled like emeralds. This was not the only case in which beetles contributed to the Great Exhibition; for in the collection of pharmaceutical substances

exhibited by the London druggists, was a large quantity of beetles, of the kind called Spanish flies or blister-beetles, on account of their active, irritating qualities when applied to the skin. Other insects, not far removed from these in natural affinities, were also present in numbers corresponding with their importance as affording, from their dried bodies, the valuable crimson dye called cochineal. The cochineal insect is obtained in large quantities from Mexico, the British West Indies, the United States, and Guatemala. An estimate, taken a few years since, gave one million pounds weight as the amount of our annual importation of cochineal; and in every pound there were not fewer than seventy thousand insects. At such a sacrifice of insect life are our arts and manufactures supplied with this valuable dye. The cochineal insect lives on a species of cactus, and may be seen alive in one of the hot-houses at Kew, feeding on its favourite plant. The Great Exhibition was not without its display of living insects; for there, before the eyes of thousands of visitors, worked away cheerily the steady, industrious bees. Openings in the Crystal Palace, communicating with their hives, allowed of their free exit in search of honey; and having gathered from the gardens of Kensington and its neighbourhood the needful supply, they came back to store it in the waxen cells which they had constructed in this novel situation. It was an excellent idea thus to exhibit the improvements in glass-hives, and the various modes of keeping bees, while the busy workers were themselves affording an illustration of England's persevering, ceaseless industry.

Molluscous animals were chiefly represented in the Exhibition by the ingenious arrangement of their shelly coverings in the form of vases, baskets, &c. An elegant epergne was exhibited, composed entirely of shells gathered from the shores of the Bahamas, arranged as cornucopias filled with flowers, in great variety of colour and beauty. Also a large vase from the same islands, with a group of flowers composed entirely of pure white shells. Shell bracelets from Dacca, with a half-moon saw, and complete set of apparatus used by the bracelet-makers, were curious. There were also interesting specimens of the conchology of Jersey, among which was the *Oreille de Mer*, a shell-fish abundantly found in that island, and used in a variety of ways for food, while the shell is preserved, and exported to England, where its pearly iridescence causes it to be valued in ornamental papier maché works. There were also vases and table-tops, from the Channel Islands, richly ornamented with wreaths of shells. The little island of Herm affords an immense collection of interesting shells, in which the greater part of the devices were executed. Bouquets in shell-work from the Mauritius, specimens from the Eastern Archipelago, and leaves, baskets, and flowers, in the same material, from France, completed the large amount of shell-work displayed in the Exhibition. The so-called *shell* of the tortoise, which is merely a bony covering, and different in structure from true shell, was displayed in its natural state, and in a variety of beautiful fancy articles, from Ceylon, the Eastern Archipelago, France, Trinidad, &c. The beautiful lining of oyster-shells, known as mother-of-pearl, was manufactured into articles of great beauty, while a profuse display of the pearls themselves, the produce of the pearl-oyster, or rather mussel, were very interesting to look upon, though they are, in fact, a proof of disease in the animal which secretes them. Pearls are produced when the transparent envelope of the animal, called the mantle, is wounded or irritated. There are small, boring worms, which pierce the shell and penetrate to the body of the animal. The mantle then sends forth a quantity of pearly matter over the wounded spot, and this becomes a little knob or pearl. Grains of sand, or other minute substances, entering the shell, are in the same way coated over with pearly matter.

Birds supplied to the Great Exhibition a variety of attractive objects, foremost among which was a collection of elegant dyed plumes, in the western main avenue; groups of plumage were also sent by France, the Netherlands, the United States, Van Diemen's Land, South Africa, &c.; and there were feather tissues, feather flowers, brooms, and bonnets, the last-named being of novel manufacture, and intended to unite lightness with warmth and porosity, in every variety of colour. But the ornamental uses of feathers are trivial indeed, compared with the substantial comfort and luxury they yield, as bed-feathers. Every variety of couch and coverlet was probably to be found in the Exhibition, from that used by princes to that employed in hospitals and charitable institutions. The luxurious eider-down, whose elasticity is such that two

handfuls of it when released from pressure are sufficient to fill a quilt; the valuable feathers of swans and geese, and all the varieties of material for bedding, were there fully represented.

It was impossible to review all the treasures supplied to us by the plumage of birds, without being struck with the wonderful nature of the object itself, as adapted first to the uses of the feathered race, and subsequently to our own. The rudiment of a feather is a kind of bulbous root implanted in the skin, and bearing a little tuft of down. A considerable portion of this down, however, soon falls off, and in its place minute cones spring up, which in a few days become elongated into cylinders, pointed at the extremity. Within these cylinders those wonderful operations go on which end in the development of perfect feathers, and which have been likened to the proceedings in a large manufactory. For within each cone, in the first place, the laminæ and fibrils which are to form the vane or plume are actually cast in moulds and left to harden, the moulds themselves being exceedingly curious objects, forming a series of narrow membranous cells separated by partitions. When these moulds are all filled with material for the vane, then the shaft is commenced, and the laminæ are united to its sides, the material for all these processes being supplied by the bulb. As the operations proceed, the parts completely formed being exposed to the action of the air soon lose their protecting capsule, which falls off in shreds, and leaves the successive portions of the feather to come forth, unfold, and assume their proper shape. How beautiful this shape is, and how wonderful the mechanism that formed it, will be felt as we survey such plumage as that of the peacock, where every point of every colour must have had its distinct producing vessel, and every different colour and gradation of tint must have demanded one of different powers. Yet there is no error of pattern, shading, or drawing in all those beautiful "eyes" on the peacock's plumage. They are perfect and exact, though produced by the most complicated means. "Every feather," says Paley, "is a mechanical wonder; their disposition all inclined backward, the down about the stem, the overlapping of their tips, their different configuration in different parts, not to mention the variety of their colours, constitute a vestment for the body so beautiful, and so appropriate to the life which the animal has to lead, as that, I think, we should have had no conception of anything equally perfect, if we had never seen it, nor can now imagine anything more so." A considerable part of the down in birds, as we have said, falls off on the appearance of the true plumage, but in the case of aquatic birds a larger portion of it remains. This forms a covering of great warmth and lightness, and is also applicable to our use for purposes of ornament as well as utility. Swan-down is a favourite material for trimmings, and in the Exhibition the down of the young adjutant crane was shown to advantage in the form of muffs, tippets, &c., from Commercolly. Before leaving the birds, we must notice the curious restoration of the dodo which was attempted at the Exhibition, and which led to the following remarks from Professor Owen. "The bird which has here been restored, from the most authentic portraits extant, was formerly a native of the island of Mauritius, where it was discovered by Vasco di Gama in 1497. The species was found there in abundance by the Dutch between the years 1598 and 1600, soon after which it appears to have become extinct. A stuffed specimen which formed part of Tradescant's Museum in 1600, passed, with the rest of the collection, into the hands of Dr. Ashmole, and was transferred by him to the University of Oxford, where it was destroyed in 1755, with the exception of the dried head, and one foot, which are still preserved. The foot of another specimen is in the British Museum. From the shortness of the wings, which were inadequate to purposes of flight, most naturalists have classed the dodo with the cassowary and other struthious birds: some have supposed it to be a kind of vulture, others a sort of dove. It is the type of a distinct family, the peculiarity of which may be estimated by the discrepancy of opinions respecting its affinities."

Passing from the feathered race, we come to huge animals inhabiting the seas, but characteristically distinguished from fishes by their warm blood, by their mode of respiration, and by suckling their young. The valuable produce of the whale, together with the weapons for his destruction, were conspicuous in the great Exhibition. Whalebone, as it is called, though really having nothing of the nature of bone in it, is an appendage to the upper jaw of the whale, by which it is enabled to secure and retain the small floating animals on which it prin-

cipally subsists. In the place of teeth the whale is furnished with a single longitudinal series of plates of this substance, on each side of the upper jaw, and these plates end in a fringe of bristles. There is also an inner row of smaller subsidiary plates arranged obliquely. The plates depend vertically from the jaw, and when the capacious mouth is opened, the water rushes in, and is strained through this natural filter, while the animals contained in it are entangled in the fringed margins of the plates, and then swallowed.

In the true whale (*Balæna mysticetus*) there are about two hundred plates on each side of the mouth in the outer row only, and these are from ten to fifteen feet in length, and about a foot broad at their base. It has been proposed to call this substance *baleen* instead of whalebone, and the term is now frequently used in books. There were baleen plates in the Exhibition from Greenland, from the north-west coast of America, from the South Pacific Ocean, from the western coast of Australia, &c. Numerous examples were also given of the purposes to which this substance is adapted by its light, elastic, flexible properties. Among others, the fine shavings into which it is reduced for the purpose of platting like straw, and thus forming a material for light and elegant bonnets, were not to be overlooked. As the substance takes a good dye, it is capable of almost endless application in an ornamental way, while its uses in connexion with machinery, in those cases where elastic brushes have been found so much more desirable than stiff heckles, have already come under notice in this work, and were likewise admirably illustrated in Plummer's Flax-breaking machines, as well as in other descriptions of machinery in the Exhibition. The use of whalebone in brooms for the sweeping of streets, chimneys, &c. and the misuse of the same substance in the stiffening of corsets, are matters of everyday experience. Both were obtruded on public attention at the world's gathering.

Quadrupeds took their place in the Great Exhibition, in some cases in their natural form. Thus a noted fox-hound, bearing an exact resemblance to the living animal, with the points fully developed, was exhibited, to show the advantages of the inventor's (Dr. Beevor's) plan of taking a complete model of the animal in gutta-percha after the removal of the skin. The model being completed, and the skin placed on it, the life-like appearance of the animal is preserved in a remarkable manner. Interesting cases of wild animals and birds were to be seen in various parts of the English department, while Canada, the United States, Western Africa, &c. sent specimens of prepared animals, birds, or fishes. Among the contributions of South Africa was a male water-boc, killed 2,400 miles from Capetown in Kafir-land, and said to be the only specimen ever brought to Europe. Formidable-looking specimens of the fur-bearing animals were also to be seen peeping forth into the nave from recesses hung with the skins of their brethren. But of all the stuffed animals in the Great Exhibition, none were so popular as those from Germany which represented boar-hunts, badger-hunts, &c., with a grotesque history of Reynard the Fox, in which the various characters were sustained by the real animals. A constant crowding to the spot, and frequent bursts of laughter from juvenile spectators, told how highly English children appreciated this novel attempt to bring the incidents of a fable visibly before them. In the south gallery of the English department was a curiosity in the way of stuffed animals that excited much interest. This was a South-Down ewe, seven years old, which had never been shorn, and which looked half-buried under its accumulated annual fleeces. These weighed no less than thirty-six pounds. The value and importance of wool to this country made the numerous samples of that substance throughout the building very attractive to connoisseurs. Those transmitted from Germany were preeminent. The fineness and elasticity of fibre of the produce of Silesian and Saxon flocks gained the highest praise. The wool from the merino sheep of Spain, once so celebrated, still maintained its excellence, but did not show the improvement which has been made in the same variety in Germany.

The specimens of merino and other wools in the French department displayed much care and skill in the management of flocks, especially those from a peculiar variety of the merino breed, exhibited by M. Graux. It appears that four-and-twenty years ago a ewe in the merino flock on M. Graux's farm produced a male lamb which became remarkable for a smooth silky character of fleece, altogether different from the curled elastic coat of merino lambs in general. The progeny of this ram included both kinds of fleece, and those of the silky character

became in the course of years a flock sufficiently numerous to enable the proprietor to sell examples for exportation. The fine silky wool from these sheep is remarkable for its qualities as a combing wool, owing to the length, strength, and fineness of the fibres. It is valued by the manufacturers of Cashmere shawls, as imparting a strength and consistence to the material, not obtained from the pure Cashmere alone. The merino wools of New South Wales were also exhibited, though not abundantly. Russia sent specimens of fine unwashed goats' hair. India contributed wool from the sheep, lamb, and camel, with goats' hair from Thibet, Persia, and Hindostan. There was an interesting collection of specimens of the wool of Cashmere goats kept by H. R. H. Prince Albert at Windsor, with examples of the fine and coarse fabrics which may be manufactured therefrom.

Passing from domestic and familiar specimens of quadrupeds, we come to the huge elephant which stood, richly caparisoned, in the Indian department, and which was represented in another part of the Exhibition by a collection of enormous tusks, and again throughout nearly every part of the building by works in ivory. The best ivory is obtained from the tusks of wild elephants, domestication being unfavourable to the quality and size of the tusk. A pair of tusks from an animal killed near the newly-discovered lake Ngami in South Africa, weighed 325 pounds; each tusk measured eight feet six inches in length, and twenty-two inches in circumference at the base. There were also tusks of the narwhal, the walrus, and the hippopotamus, which produce a dense and white ivory, but not the beautiful grain or markings of the true ivory.

The fur-bearing animals of the Great Exhibition were numerous and attractive, the stuffed animals frequently accompanying the collection of skins. The fine collections of furs of the Hudson's Bay Company and other extensive importers in the English departments afforded an interesting study. In the foreign departments, karosses, or Kafir cloaks, from South Africa, made of the skins of wild animals, many of which in that region are of great beauty, deservedly attracted notice. Costly sleigh-robes from Canada, made from the skins of bear, wolf, and fox, represented the winter travelling-costume of the upper classes of that country. Skins of brush kangaroo, black opossum, native cat, and tiger cat, from Van Diemen's Land, were exhibited in the form of rugs of great beauty. Opossum fur was also made into a lady's cape. Russia sent sheep, goat, lamb, and antelope skins. Among the Austrian collections were fur vests, black lamb skins, and a Banda, or Hungarian cloak of furs. The United States had various furs, among which some choice skins of the silver-martin, manufactured into articles of lady's dress were very beautiful. Sweden sent cloaks lined with the skins of Swedish martin and squirrel, a stuffed silver bear-skin mat to place under a writing-table, and a fur coat made of the skins of rein-deer calves. Very characteristic also was the skin-tent in the Tunisian department. This was a tent of sailcloth, on which were stretched skins of lions, leopards, wild sheep, &c.

Of the application of the skins of animals to use as leather, and of their wool and hair as a material for cloth, felt, &c., it would be endless to speak. The long avenues devoted to the exhibition of woollen goods proved how large and important is this branch of manufacture, while novel applications of beaver, mohair, &c., in woven fabrics, showed that invention is alive in this, as in every other department of the useful arts. The immense display of leather and hides throughout the exhibition also bespoke attention to the commercial value of those articles. England had thirty-five exhibitors, the Zollverein the same number, France had sixty, Russia fifteen, Switzerland twelve, Austria eight, Belgium seventeen, Portugal twelve, Canada six, Egypt six, Van Diemen's Land four, South Africa four, West Africa three, United States three, Greece two, Spain two, New Zealand two, Brazil, Gold Coast, and Sardinia, each one. These, with some few others, showed the very wide extension of the knowledge of the preparation of leather throughout the world. It is, in fact, an art with which every savage is in a measure acquainted, the skins of beasts being his natural and most available material for clothing and shelter, and the art of softening and preparing them being one of the necessities of his condition. Besides the hides and skins above mentioned, there was an almost infinite number of leathern articles of use or ornament in the various departments. Specimens of

variously dyed leather, leather cloths, leather-making machinery, leather clothing, leather stained in imitation of wood, a rich and multiform display of leather bindings for books, met the eye at every turn. In the Fine Arts Court there was also a good exemplification of the use of leather in works in relievo, grained to imitate various woods. A panel of a room richly finished in this style gave an idea of the effect of this mode of decoration for halls, dining-rooms, &c. Cornices and window ornaments in gold and silver, of which the foundation was leather, showed the application of this substance to the delicate forms of flowers, fruit, &c. There were also tables, chairs, bookcases, picture frames, and various other articles mounted with reliefs in leather.

The skins of animals thus variously employed, naturally led the mind to other animal products, such as bone, horn, and hair, which, in addition to wool and fur, (already alluded to,) contributed to swell the lists of this division of the Exhibition. The ordinary uses of the bones of animals as a substitute for ivory in knife-handles and other objects are well known: it was for our German brethren to teach us what elaborate carvings might be executed in this common material. A Silesian contributor sent a curious example of his industry, being a landscape and several figures of animals, in a very diminutive size, cut out of bone. Bone dust was also to be found in the Crystal Palace, for that wonderful edifice included numerous substances used as manures, nothing being too mean for admission there, which was likely to serve the purposes of agricultural or manufacturing art. The earthy salts which constitute the hard part of bone are phosphate and carbonate of lime, with a minute quantity of sulphate of lime, and traces of phosphate of magnesia. These substances are highly invigorating to the soil, and afford a powerful and valuable manure. Another useful product of bones is animal charcoal, a residue obtained from carbonized bone, during the process of freeing the same from phosphate of lime. Several varieties of animal charcoal, designed for use in the refining of sugar, were displayed by a French exhibitor. Countless illustrations of the use of horn appeared in the several cutlery departments of the Great Exhibition; but there were also beautiful examples of horn in its natural state. Canada sent enormous palmated antlers of the elk, together with skins and hides of the same animal. South Africa furnished an extraordinary pair of polished ox horns, (with head complete,) measuring from tip to tip eight feet four inches, and twenty-one inches in circumference. These were from Port Natal. There were also buffalo horns and hides, and the teeth of a sea-cow. Egypt sent horns of wild bulls and goats, antelopes and gazelles. Turkey sent buffalo and other horns, with an immense collection of skins of bear, wolf, lynx, wild cat, badger, weasel, otter, beaver, deer, fox, leopard, &c. India sent numerous and very fine examples of horns and antlers, as those of the great Arné buffalo, and gour, with those of numerous deer, whose names are not very familiar, as the bárah sinha, the samber, the barking deer, the axis, the hog-deer, &c. Among the curiosities connected with the manufacture of horn were brooches, watch keys, shirt buttons, and rings, made of chamois horn by a Swiss exhibitor, and some transparent horn paintings from Hamburgh.

The hair of animals, though of less extensive use, is yet in the article of horse-hair alone of great importance. This strong and elastic substance is obtained in such considerable lengths, that it can be employed in weaving plain and figured fabrics; numerous examples of horse-hair cloth, plain, and woven in patterns, were exhibited. There were specimens also of English black horse-hair in a curled and manufactured state, and in the raw state. Belgium sent specimens of improved horse-hair damasked furniture stuffs, both sides alike; also specimens of dyed horse-hair; and of the kind used for sieves, brushes, &c. Hamburgh sent prepared horse-hair, and the Netherlands displayed many varieties. Some of extreme length were for weaving cloth for couches; others of ordinary length were for weaving cloth for seats or benches, while the short lengths served to weave sieve cloths or to make brushes. The elastic stuffing for seats is obtained by first making horse-hair ropes, and then boiling them. When unwound, the hairs retain their twisted form and elastic character. But the most remarkable collection of horse-hair was sent from Russia. A manufacturer of St. Petersburg sent black and white horse-hair of great length and beauty.

There was a sample of white horse-hair from the tail, 40 inches in length, and of the first quality. In the black tails the hairs were 42 inches long. White hair from the mane was also shown, from 28 to 30 inches in length, both transparent and opaque. Horse-hair adapted for furniture, twisted and untwisted, black, grey, and white, completed these excellent specimens. A similar collection, by another manufacturer from the Russian capital, included plumes of buffalo-hair of different colours, and of horse-hair dyed crimson. Switzerland exhibited bullocks'-hair and horse-hair; a bundle of curled horse-hair appeared among the productions of Van Diemen's Land. A manufacturer of Elberfeld sent horse-hair woven with silk and cotton for upholstery. Black horse-hair with red silk, and white with blue silk, had a pretty effect. Horse-hair cloth was to be seen in many other departments, and durable horse-hair clothes-lines were also exhibited. So delicate a manufacture even as that of lace, is executed in this unpromising material. Horse-hair and silk lace, horse-hair and straw blonde lace, together with a lace made of hemp, silk and horse-hair, were sent from the Canton of Argovie, Switzerland. The finest specimens of bristles were sent by Russia, to which country that article forms a most important branch of trade, its exports of bristles amounting to about two million pounds weight annually. India, Belgium, and Germany also contributed bristles, those from the first-named country being the produce of the wild-boar and the elephant. The application of the finer qualities of bristle, and the extensive use of sable for the purposes of the artist, were illustrated by numerous and complete collections of every form of brush and tool used in painting. Camels' hair for such purposes, as well as camels'-hair cloth, was also exhibited by Russia, Turkey, and Tunis. A novel use of the hair of the rabbit and hare was made known by a Spanish contributor. Removed from the skin by a mechanical process, it is put to the same uses as down, and forms a cheap and abundant substitute for that material.

Few persons can have failed to notice the extensive employment of gelatine in an ornamental way at the Great Exhibition. The great improvement in the manufacture of this substance is thus noticed by Prof. Owen:—"The most remarkable progress in the economical extraction and preparation of pure gelatines and glues from the waste remnants of the skins, bones, tendons, ligaments, and other gelatinous tissues of animals, has been made in France, where the well-organized and admirably arranged establishments for the slaughter of cattle, sheep, and horses in large towns, give great and valuable facilities for the economical applications of all the waste parts of animal bodies. Among the beautiful productions of this industry, the specimens exhibited by its chief originator, M. L. F. Grenet, merited peculiar approbation. They included different kinds of gelatine in thin layers, adapted for the dressing of stuffs, and for gelatinous baths, in the clarification of wines which contain a sufficient quantity of tannin to precipitate the gelatine: pure and white gelatine cut into threads for the use of the confectioner: very thin, white, and transparent sheets called papier glacé, or ice paper, for copying drawings: and, finally, a quantity of objects of luxury, or ornaments formed of dyed, silvered, or gilt gelatines, adapted to a variety of purposes, and to the fabrication of artificial or fancy flowers." Large groups of gelatine flowers were to be seen in several parts of the Exhibition, richly coloured, and in some cases closely imitating nature. But in general the glittering, semi-transparent nature of the material gave the effect of flowers drenched with rain. Akin to gelatine is isinglass, which consists of the dried and purified membranes of certain fish, chiefly of the sturgeon kind. This substance is naturally separable into delicate fibres, which act mechanically in the clarification of wines and malt liquors. Various qualities and states of isinglass were exhibited, with illustrations of its use in the preparation of gelatinous products for culinary purposes.

Section XIII.—Chemical and Pharmaceutical Processes and Products.

The chemical manufactures of this country have sprung into existence and importance with a degree of rapidity which would be marvellous in any other country possessing more leisure and less capital and energy than our own busy island. Some of our chemical works occupy an area equal to that covered by the Great Exhibition building, and are attended by a

collection of work-people equal in number to the population of a small town. Many of the chemicals exhibited were of colossal proportions, as if to represent the magnitude of the works in which they were produced. Thus, some of the masses of *alum* were 8 feet high. There were also enormous groups of crystals of *tartaric* and *citric acid, prussiates* and *chromates of potash, sulphates of copper* and *of iron.* These crystals formed, as it were, landmarks to guide the visitor to the places where the chemicals were exhibited. And so beautiful in colour, perfect in form, and fantastic in grouping, were many of the crystalline masses, that it was even proposed to employ them as drawing-room ornaments. Some of the single crystals, especially the octahedra of alum, exhibited by Mr. Copney, were of perfect form, extraordinary size, and marvellous beauty. These crystals were prepared by a careful system of nursing during several months. In the first place, a hot solution of the salt is made, and in it is suspended a hair or thread. As the solution cools, single crystals become deposited upon the hair as a nucleus. A perfect crystal is selected, and detached, and placed in the solution, where it is left to increase in size; a small portion of a concentrated solution of the salt being added, from time to time, to feed the nurseling. If the solution be too strong, groups of small crystals are formed: these must be removed. The crystal must also be turned every day, so that all parts may be equally acted on by the light. The crystals of chrome-alum, sulphate of copper, sulphate of magnesia, &c., prepared in this way, excited general astonishment.[1]

The chemical substances exhibited may be naturally arranged into two groups, according as they are produced in the chemical factory, or prepared in the scientific or pharmaceutical laboratory. The large scale upon which our chemical factories are conducted, has been already adverted to; and in alluding to our great alkali works, in which from 50 to 60 tons of common salt are used every week, in the production of caustic soda, or carbonate of soda, the Editor of the Official Illustrated Catalogue well remarks:—"The fires of the kelp-burners on the shores of the islands of Scotland are scarcely now extinct, when vast factories, employing large numbers of individuals appear, to produce in enormous quantities the same alkali which was, until recently, derived from the fused ashes of marine plants." The manufacture of *soda* from salt was admirably illustrated by Mr. Stevenson, of Jarrow, South Shields. His case contained the following specimens:—1. Common salt from Cheshire, sulphuric acid, and iron pyrites, used as a substitute for the sulphur. 2. Sulphate of soda, produced by the action of the sulphuric acid on the salt. 3. Ball-soda, or black ash, prepared by fusing sulphate of soda with coal and chalk. 4. Soda salt, or soda in an impure state, obtained by evaporating a solution of the calcined product, No. 5. 5. Rough soda ash, which, dissolved in water, purified and crystallized, produces crystals of soda. There were also specimens of refined soda ash, made by purifying No. 5, and containing 51 per cent. of alkali: also pure soda ash, $58\frac{1}{2}$ per cent., containing no caustic soda: also specimens of bicarbonate of soda, made by exposing crystallized soda to carbonic acid gas. The manufacture of alkali from sea-weed is not, however, altogether abandoned, but the manufacturer now obtains from it the *iodine*, an article of great commercial value, which was formerly wasted. Specimens were exhibited by Mr. Ward, of Ramelton, county Donegal, of kelp, iodine, muriate of potash, sulphate of potash, and alkali salt, all manufactured from sea-weed.

The great chemical factories of Liverpool, Newcastle-upon-Tyne, Glasgow, Birmingham, &c., were represented in the Exhibition. There were fine specimens of *blue* and *green vitriol,* of *alum, tartaric acid, citric acid,* the *acetate,* and other salts of *lead.* Among the latter may be mentioned the *neutral oxichloride of lead,* a new pigment of great body, and of a brilliant white colour, discovered by Mr. H. L. Pattinson. It is made by dissolving galena or sulphuret of lead in muriatic acid, so abundantly formed as a waste product in the manufacture of soda, and other processes. By this means, the sulphur of the galena is expelled as sulphuretted hydrogen gas, which may be burnt to form sulphuric acid; and the silver and lead contained in the ore are converted into chloride of silver and chloride of lead. The mixed chlorides are treated with hot water, when the chloride of lead dissolves, and the insoluble chloride of silver

(1) Mr. Copney informs the Editor that he has since prepared other crystals, the dimensions and weights of which are nearly twice those of the crystals exhibited. One of them, a crystal of chrome-alum, has a weight of two pounds.

subsides, and is collected and reduced into metallic silver. Lime-water, in proper proportion, is added to the solution of chloride of lead, when the whole of the lead is precipitated as neutral oxichloride, which, being collected and dried, forms the pigment. Three pictures, painted by Carmichael a year before with this pigment, were also exhibited; together with specimens illustrative of the manufacture, which promises to become of importance. The manufacture of *white lead* was well illustrated, and there was also exhibited its substitute in house-painting, and for other purposes,[1] viz.; *white zinc*, or oxide of zinc, already mentioned at p. cxii. of this essay. It is stated in Hunt's Hand-Book, that this zinc-white,

> although of a beautifully white colour, is unfortunately, to a certain degree, transparent; and it is stated by painters, that it does not possess the covering properties, or the body of the carbonate of lead. Another difficulty attending the use of zinc paint, arises from the circumstance that it remains on the wood a long time before becoming sufficiently hardened to admit of a second coat being laid on; whilst as most of the compounds sold under the name of *patent dryers* contain lead, the introduction of this substance gives it the property of becoming black when exposed to sulphuretted hydrogen, and thus entirely destroys one of its most valuable characteristics. This arises from the fact, that the oxide of zinc will not combine with oil to form a plaster, in the way in which the oxide of lead does. It is much to be wished that the resources of modern chemistry may be at length found equal to the removal of this disadvantage; as from the baneful influence exerted by white-lead, both on the persons who are employed in its manufacture, and on the painters by whom it is applied, it is greatly to be desired that some good and equally cheap substitute for this substance may be discovered.

The *bichromate of potash*, and salts of *chromium*, were exhibited on a large scale, and in great beauty, as were also the *red* and *yellow prussiates of potash*, and *Prussian blue*. The latter, in its common form, is insoluble, but Mr. Reade exhibited it in a soluble form, prepared by adding nitric acid to the yellow prussiate of potash in solution, to which is immediately added a solution of sulphate of iron. The mass becomes a blue paste, to which water is added, and the whole is then thrown upon a filter, and washed with water until a solution of iron ceases to give a blue colour to the water drained off. The precipitate left on the filter, is a fine Prussian blue, perfectly soluble in rain-water, in which state it may be used as a writing fluid and a dye.

The *smalts* and *artificial ultramarines* of Germany and France were exhibited in great variety, some idea of which may be formed from the number of signatures attached to the specimens of the Schwarzenfels smalt,[2] and the Wermelskirchen ultramarine; the former amounting to upwards of thirty, and the latter to sixty. True ultramarine is obtained from *lapis lazuli* by a curious process, which we propose to describe fully in our article on the subject, together with a variety of details respecting the artificial compound which is now manufactured in such abundance, and sold, often, for as many pence per pound as the genuine article, of the finest quality, fetches pounds per ounce. The genuine ultramarine had been analysed many times by distinguished chemists, and was known to consist of sulphur, silica, soda, and alumina. Traces of iron and carbonate of lime were also found, but these were supposed to be accidental impurities. Many attempts were made to produce ultramarine synthetically, or by direct combination of the ingredients which analysis afforded, but without success, and the attempt was given up as hopeless, when it was remarked by Tassaert, the superintendent of the soda department of the plate-glass manufacture of St. Gobain, that in pulling down one of the furnaces used in the manufacture of soda, a blue powder was found, which was examined by Vauquelin in 1814, and found to possess the characters of true ultramarine, particularly that of being decomposed by powerful acids with the liberation of sulphuretted hydrogen. In 1827 Gmelin, being at Paris, informed Gay Lussac and other chemists that he was then occupied in experiments on the formation of artificial ultramarine. On the 4th of February, 1828, Gay Lussac announced to the Academy of Sciences at Paris,

(1) The other uses to which zinc-white is applicable, are stated by the exhibitors to be for paper-staining, card-enamelling, bleaching of lace, glazing of ware, and for the down of artificial flowers.

(2) The specimens illustrative of the manufacture of smalt at Schwarzenfels, were contained in square bottles, numbered and lettered as follows:—1. SFFFC. 2. SFFC. 3. FFFFCF. 4. FFFCF. 5. FFCB. 6. FCB. 7. FH. 8. MCB. 9. MC. 10. OCF. 11. OH. 12. OC_2. 13. OC^3. 14. Streublau. 15. MSB. 16. SFFFE. 17. SFFE. 18. FFFFE. 19. FFFE. 20. FFE^2. 21. FE_2. 22. ME. 23. MEBS. 24. OE. 25. OE_1. (NOC.) 26. OE_3. 27. OE_3. (NOC_2) 28. OE^4. 29. OSE^1. 30. BC. 31. FH violett. 32. FFCF violett. 33. FFFE violett. 34. FE^1 violett. 35. Zaffers FFS. 36. Zaffers FS. 37. Zaffers MS. 38. Box of Nickel-speise. 39. Nickelspeise roasted. 40. Oxide of Nickel. 41. Box of Nickel. An account of the manufacture of smalt will be found in the Cyclopædia, under the article COBALT, p. 400, and at greater length in a paper by the Editor, contained in the Pharmaceutical Journal for May 1851.

that M. Guimet had succeeded in making artificial ultramarine, but that he wished to keep the process secret. Whereupon, Gmelin immediately published his process, and complained that his confidence had been abused; to which Gay Lussac replied, that he knew nothing whatever of M. Guimet or of his researches, until a specimen of the artificial ultramarine had been sent to him from Toulouse, where Guimet resided, for the purpose of showing it to the Institute: that the idea of forming artificial ultramarine was by no means new, since the Société d'Encouragement des Arts, &c., of Paris, had four years before offered a prize of 6,000 francs for such a discovery. Guimet himself also wrote, that in July 1827 he had distributed his artificial colour among several artists, who estimated it highly; that Gmelin's published method would be of advantage to Science, but not to the Useful Arts, because it was far too complex and expensive. By the year 1831, Guimet had established a large factory near Lyons, for the production of his ultramarine, and it had already begun to supersede the more expensive cobalt blue and smalt in the manufactories of France: its price, at that time, was 60 francs per pound for the finest quality, and 20 francs for the second quality. We mention these particulars, which have cost us some research among original authorities, because several erroneous accounts respecting the history of artificial ultramarine have been published. The manufacture was introduced into Germany at a later period, and is now carried on extensively at some of the small towns on the Rhine. The manufacture has very recently been introduced into England, but it is in the hands of foreigners. At the Great Exhibition, the artificial ultramarine on the English side was by Kurtz and Schmersahl, of Manchester; by Picciotto, as manufactured in London by Hochstätter's process; and by Dauptain & Co., of the City Road, London. Guimet has not published his process: the Germans have been more liberal, they having published, at different times, a number of recipes in detail,[1] some of which fail in practice, others are too expensive, and one or two depend, to a certain extent, upon the skilful application of the materials furnished by the locality of the manufacture.

A great variety of *colouring matters*, and preparations used for producing colour on cotton, linen, silk, and wool, were exhibited, and many of them were new. There were interesting specimens of the application of *orchil* and *cudbear*, (which have long been used in dyeing wool and worsted,) to the dyeing and printing of cotton. Attempts had been made to render cotton similar in character to wool by the action of acids; but this attempt at *animalization*, as it was termed, did not succeed. It was found by M. Brocquet, that by preparing the piece on the warp with albumen or solution of casein, the alum took tolerably well, but it was not permanent. Mr. Lightfoot has recently discovered that cotton prepared with oily matters possesses an extraordinary attraction for the orchil colour. Messrs. Hargreaves Brothers & Co. exhibited some beautiful cotton prints illustrative of this discovery, as also of that by Mr. John Mercer, which consists in subjecting cotton and other fibrous materials to the action of caustic soda, or sulphuric acid, whereby the fibres become contracted and *fulled*, converting thin and coarse cloth into strong and fine; at the same time giving greatly increased and improved powers of receiving colours in printing and dyeing, and also in making them more permanent. If very fine calico, containing 180 picks to the inch, be thus treated, it contracts to calico of 260 picks to the inch, a degree of fineness which has not hitherto been attained by mechanical contrivance. With reference to this discovery, Professor Solly remarks:—

> The fibre of cotton, when examined by a lens, is found to consist of a flattened or ribbon-shaped tube. When treated with a cold strong solution of caustic soda, as in Mr. Mercer's process, it appears to shrink, and assumes the form of a simple cylinder. Thus, three important and very remarkable alterations occur at the same time,—the fibre becomes stronger, it acquires increased attraction for colouring matter, and it becomes smaller; the process is at once cheap and effectual, and the cotton is decidedly increased in value. In most cases, where chemical agency is applied in the preparation of vegetable fibres, either to remove impurities, to destroy colour, or, indeed, for any other purpose, the object in view is generally attained at the sacrifice of a little strength. It is therefore a peculiar feature of this discovery, that the valuable properties conferred upon the cotton are not only not gained at the sacrifice of its strength, but, on the contrary, are even accomplished by an increase of tenacity.[2]

(1) Several of these are given in the third volume of Gmelin's Hand-Book of Chemistry, an excellent translation of which has been published by the Cavendish Society.

(2) Lecture to the Society of Arts, "on the Vegetable Substances used in the Arts and Manufactures, in relation to commerce generally."

Another important discovery by Mr. Mercer must also be noticed. The French mousseline-de-laines are formed altogether of wool, while the cheaper ones of England consist of wool and cotton. The colours on the latter are, however, very inferior to those on the former, but the mixed fabric acquires the properties of the other, by being treated with a bath of chloride of lime.

Among the many curious facts brought to light by the Great Exhibition, was the manufacture of *artificial essences* of pine-apples, pears, and other fruits. It has long been known, that one of the volatile acids of butter, the *butyric*, by being converted into an ether, imparted the flavour of the pine-apple to rum, so that the celebrated *pine-apple rum* obtained its distinguishing name from a compound prepared, in the first instance, from butter or putrid cheese. Butyric ether has been obtained from the fruit itself. By continuing the inquiry, it was found that the fœtid fusel oil, which is separated from the crude spirit in the process of the rectification of brandy and whiskey, when distilled with sulphuric acid and acetate of potash, yielded an essence of *pears*. The fusel oil, distilled with sulphuric acid and bichromate of potash, afforded an essence of *apples*. In a similar manner, it was found that the flavour of the green gage, apricot, black-currant, and mulberry, could be very well imitated, although less perfectly than those of the pine-apple and jargonelle pear. In the concentrated form of these essences, the smell is acrid, but when diluted, the odour of the fruit is recognised. They are quite harmless in the proportions used, viz.—a drop, or half a drop to the ounce, and it is probable, that few out of the many thousands of persons who refreshed themselves with ices in the Great Exhibition were aware that the chemistry of the laboratory, instead of that of the orchard or the fruit garden, had supplied the much-admired flavour. No less curious is the fact, that some of the most admired *perfumes* are now not prepared, as of old, by distilling them from flowers, but by chemical artifices, similar to those just noticed. The fusel oil was made further interesting by the exhibition by Mr. Barnes of a series of new compounds,—the salts of *valerianic acid*. This acid is contained in small quantity in the volatile oil obtained by the distillation of the valerian root, but it may also be produced artificially by the oxidation of fusel oil. The valerianates of zinc, iron, and quinine, have been used with great advantage in medicine.

Interesting in a scientific as well as an industrial point of view, was the specimen of *allotropic*[1] *phosphorus*, discovered by Herr Schrötter, of Vienna, and exhibited by Messrs. Sturge of Birmingham, who have the working of the English patent. Phosphorus is largely consumed in the manufacture of lucifer matches, and in its common form is dangerous both to the manufacturer and to the consumer, from the ease with which it ignites; but its effects on the operatives engaged in making the matches, are to produce a frightful disease of the lower jaw, which is often fatal. Hence, on the score of safety, as well as humanity, it was desirable to find a less objectionable substitute. This was supposed to be impossible, but chemistry stepped in, and deprived the phosphorus of its dangerous attributes, without rendering it less efficient. By distilling common phosphorus under certain conditions, at a temperature not exceeding 440° or 450°, it becomes converted into a brick-red substance, not soluble in sulphuret of carbon, not igniting under ordinary friction, or in contact with iodine, not poisonous,—distinguished, in fact, for negative properties, as common phosphorus is for active ones: and yet this wonderful change appears to be only molecular; that is, the phosphorus is not converted into a compound; it has combined with nothing, it has lost nothing; but its particles have, probably, arranged themselves with respect to each other in a manner different from that of the particles of common phosphorus. Heated above 450°, the allotropic phosphorus explodes, and becomes common phosphorus: mixed with the usual ingredients of lucifer matches, it ignites readily by friction, a circumstance which constitutes another of its remarkable and useful properties.

The articles of the Materia Medica made a goodly display; they were collected in groups to show the varieties, and this remarkable circumstance was elicited, that the samples in the

(1) Allotropy is a term introduced from two Greek words, ἄλλος and τρόπος, to signify the different states which may be assumed by the same body.

English collection were often finer than those sent from the countries which produce them. As an illustration of this fact, Mr. Bell, in his Lecture to the Society of Arts, quoted the case of *scammony,* as shown by a series of specimens from the English collection.

No. 1 is pure; the others are more or less adulterated, down to No. 5, which is not worthy of the name of scammony. In the Turkish collection, where we might have expected to find scammony unusually fine, No. 1 is about on a par with No. 3 in those above mentioned, and No. 5 would not be recognised as scammony except by the label on the bottle. It is only within a few years that pure scammony has been known in England, and its introduction arose from the circumstance of several samples of scammony being analysed, and found to be adulterated (chiefly with starch and chalk) to an extent varying from about 15 to 60 per cent. The fact being reported to the merchant abroad, he replied, that he made it to suit the demand, and mixed it according to the price. He said he would send it pure if desired, but it would be dear in proportion. From that time 'virgin scammony,' as it is called, has been in the English market, but it has not yet found its way to the Continent of Europe. Several foreign professors, lecturers on materia medica, and possessors of extensive museums, had never seen pure scammony until they saw it at the Great Exhibition, and were glad to obtain a few ounces as a specimen to take home with them as a curiosity. Similar remarks may be made with regard to *opium,* of which we had specimens from various localities. This is a drug, which, like many others, is adulterated to suit the demand. In the Turkish collection there was pure *otto of roses,* and also *oil of geranium,* (as it is called,) with which it is usually mixed. Similar specimens were in the English collection. It is only recently that these two articles have been imported separately, and this is decidedly an improvement, as the public may now purchase some of each, and mix them according to taste. In the Indian collection, we have the *grass oil,* which appears to be identical with the so-called oil of geranium, showing that the latter name is erroneous: it is the product of one of the andropogons. In several other instances, the Exhibition has assisted in correcting errors in the identification of vegetable products, and furnished a clue to further investigation.

The dried medicinal plants exhibited by Mr. Kent possessed, in many cases, all the beauty of the living plant, preserving the characteristic smell and medicinal properties unimpaired. Instead of the old method, adopted by herbalists, of drying the plants in bunches on kilns, and then hanging them up exposed to the action of light, air, and moisture, Mr. Kent collects the plants while fresh, rejects all the stalks and dead leaves, and immediately dries them in a room heated with a current of pure air, and they may afterwards be preserved in glass or tin vessels for any length of time.

Preparations of the *vegeto-alkaloids* were exhibited in great beauty. Thus, there was one series illustrative of the salts of *morphia,* embracing opium; others illustrative of *quina, strychnia,* and *brucia;* also specimens of *bebeerin,* from green-heart bark, yielded by the Bebeern tree of Guiana; also *phloridzine,* a bitter principle, obtained from the bark of the root of the pear-tree; it is in high repute in Italy as a substitute for quinine. Among the numerous specimens of *camphor,* was the native camphor of Borneo, so highly prized by the Chinese, that it fetches seventy-eight times the price of common camphor, and is therefore rarely seen in England. *English Rhubarb,* from Banbury, in Oxfordshire, was exhibited. It appears that Mr. William Hayward, an apothecary of that place, was the first to cultivate rhubarb in that locality. In 1789, he obtained a silver medal, and in 1794 a gold medal, from the Society of Arts, for the cultivation of what he terms "true Turkey rhubarb," the plant for which the Society offered the premium being the *Rheum palmatum,* or true rhubarb; but according to Dr. Pereira, the variety cultivated at Banbury is the *R. rhapontium.*

The chemicals exhibited in the foreign departments were not, upon the whole, equal to those of Great Britain; but several of the leading manufacturers in France and Germany did not exhibit; "not," as Mr. Bell remarks,

from the fear of being left behind in the competition, but rather from an opposite cause. In the manufacture of certain chemical products, in which spirit of wine is required, the English chemist, whose spirit is heavily taxed, cannot compete with the French or German chemists, who obtain their spirit at about a fourth of the price. On this account, many products are largely imported, which would otherwise be made in this country. Some of the foreign makers of such products could have made a magnificent display at the Exhibition, but by doing so, they might have given umbrage to some of their customers. This is an inference which may fairly be drawn from the absence of certain names from the list of exhibitors; and I mention it to show the influence of high duties in crippling British industry. The difference between the spirit duty in England and in Scotland almost drives the English chemist out of the field in the manufacture of chloroform and some other articles derived from or prepared with spirit, but not coming within the definition of 'spirit mixtures.'

Section XIV.—Machinery Exhibited.

We come now to a part of our subject which it is difficult to write about without going into minute details, and employing much pictorial illustration. Indeed, in the Exhibition itself, the department of Machinery was at once the most exciting and the most disappointing of the whole display; and in no part of the building did we find visitors so eager for explanations and assistance as in this. The raw materials of industry, and the finished products in the fine and in the useful arts, were, or appeared to be, more intelligible to the popular mind than machines, whose internal arrangements were often concealed, or whose working parts were moving lazily along, doing nothing, as in the case of the large planing, drilling and slotting machines. Even in the case of that splendid series of machines which illustrated our textile manufactures, there was a great want of explanation; and it was a frequent source of regret to us, that arrangements were not made for giving to the crowds of curious visitors, without extra charge, a few short but effective explanations. This was attempted to a certain extent in the case of cotton, by attaching labels to the several machines; but the information thus conveyed was too scanty to be of much assistance to persons unacquainted with the subject. Fortunately, it will not be necessary for us to notice at any considerable length, in this Section, the machinery of the Exhibition, since a description of the more important machines will be found in the body of our work. In a few cases, however, through the kindness of Exhibitors, we shall be able to add to the value of articles which have already appeared by noticing with some detail a few of the more complex machines.

Of all descriptions of machinery, that used by the Engineer or Machinist is the most important, for on it depends in great measure the value of machines for special objects, and, consequently, the excellence of the articles manufactured. The large tools or machines of the engineer are of modern origin, and may be said to date from the time when Watt endowed the Steam Engine with almost human intelligence, thereby leading to the necessity for accurate workmanship. About the same period also, the factory system, so vastly extended, if not introduced, by Arkwright, required machines which were to work with a precision surpassing that of human hands and fingers; and as these machines were being constantly improved by men of genius, such as Hargreaves, Crompton, Roberts, Jacquard, &c. the profession of the engineer rose into permanence and importance. But up to about the time to which we now refer, nearly every part of a machine had to be made and finished to its required form by manual labour; so that accuracy and precision depended in great measure upon the dexterity of the workman's hand, and the correctness of his eye. He had no other means of applying and guiding his tool to the work in the lathe, than his unaided muscular strength; and the exertion required in turning iron was so great, that he soon became exhausted, and his work varied with his declining strength. Occasionally he could not avoid cutting too deep, which would compel him either to go over his work again, or to leave the mark of his tool in the metal. If, however, instead of working the tool by hand, it were by some mechanical contrivance held firmly to the work, and while cutting a shaving from the bar in the lathe the tool were slid gently along, it is evident the bar would be turned quite true. These objects are attained by the *slide-rest*, shown in Fig. LXV. Here the tool is held firmly by a sort of iron hand or vice, made to move in the required direction by means of the slide S, the sliding motion being given by the workman turning the screw-handle H, the depth of the cut being regulated by the under slide K, also moved by a screw handle. By the separate or combined motion of these two slides, the tool can be made to act along or across the work with perfect accuracy, the business of the work-

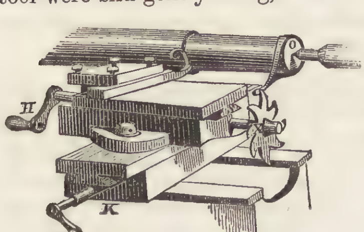


Fig. LXV.

man being confined to turning the screw-handle H. The machine may also be made self-acting in various ways, as by attaching a star X to the wheel H, and an iron finger to the end of the work in the lathe at O. It is evident that for every revolution of the work, the finger

fixed round o will bear down one of the points of the star x, the effect of which is the same as turning the screw-handle H, whereby the tool is moved along the surface of the work.

The application of the slide-rest principle in the engineer's workshop is of very extensive use in holding, applying, and directing the motions of cutting tools to the surface of the work to be turned, planed, or otherwise cut into the six primitive or elementary geometrical figures to which all the forms met with in machines may be reduced, namely :—the *line*, the *plane*, the *circle*, the *cylinder*, the *cone* and the *sphere*. According to Mr. Nasmyth, the honour of the invention is due to the late Henry Maudslay, but Professor Willis has shown that it acquired the distinct and individual form in which it now exists in a slow and gradual way. In 1648, Maignan published at Rome engravings of two curious lathes for turning the surfaces of metallic mirrors for optical purposes, in which the tool is clamped to frames so disposed, that when put in motion, it is compelled to move so as to form true hyperbolical, spherical or plane surfaces, according to the adjustment : so also in the screw-cutting lathes, fusee-engines, and other machines introduced by the clockmakers, (who were the first to employ special machines for their manufactures,) tools were guided by mechanism, "yet the real slide-rest does not make its appearance until 1772, when in the plates of the French Encyclopédie, (Tom X. Pls. 37, 38, 84, 85, 86,) we find complete drawings and details of an excellent slide-rest, as nearly as possible identical with that usually supplied by Messrs. Holtzapffel and other makers of lathes for amateurs. Bramah's slide-rest of 1794, is so different and so inferior in convenience, that the two could not have had a common origin, and we must suppose that the slide-rest was not known to that ingenious mechanist." In 1784, when Bramah obtained the patent for his admirable lock, a series of original machine tools were constructed for shaping the barrels, keys, and other parts with the precision which machinery alone can give. Henry Maudslay was educated in Bramah's workshop, and was employed in making the principal tools for the locks.

Professor Willis brings into prominent notice the services of Sir Samuel Bentham, in the construction of machine tools. The following notice will form an interesting addition to the details respecting block-machinery, contained in the article BLOCK, page 139.

From General Bentham's own account[1] it appears, that in 1791 steam-engines in this country were extensively employed for pumping mines, and for giving motion to machinery for working cotton, and to rolling-mills, and some other works in metal; but that in regard to working in wood, steam-engines had not been applied, for no machinery, other than turning-lathes, had been introduced, excepting that some circular and reciprocating saws and working tools had been applied to the purpose of block-making by the contractors who then supplied blocks to the navy; even saw-mills for slitting timber, though in extensive use abroad, were not to be found in this country. General Bentham had at this time made great progress in contriving machinery for shaping wood, as is sufficiently shown by his remarkable specifications of 1791 and 1793 ; and he informs us that, rejecting the common classification of works according to the *trades* or *handicrafts* for which they are used, he *classed the several operations that have place in the working of materials of every description according to the nature of the operations themselves*, and, in regard to wood particularly, contrived machines for performing most of those operations whereby the need of skill and dexterity in the workman was dispensed with, and the machines were also capable of being worked by a steam-engine or other power. Besides the general operations of planing, rebating, morticing, sawing in curved, winding, and transverse directions, he completed, by way of example, machines for preparing all the parts of a sash-window and of a carriage-wheel, and actually showed these and other machines in a working state in 1794 in London.

This led to his appointment as Inspector-general of Naval Works, for the purpose of introducing these and various other machines into the royal dockyards, which he immediately set about effecting. From this time (1797) the introduction of machinery for the preparation of blocks and other works in wood at Portsmouth, Plymouth, and other Government establishments, takes its origin. In 1802 the General received a most powerful and efficient auxiliary in the person of Mr. Brunel, who in that year presented his plans for the block-making machinery. His services being immediately secured, and Mr. Henry Maudslay engaged for the construction of the mechanism, the admirable series of machine-tools were finished and set to work in 1807, by which every part of the block and its sheaves are prepared.

The completeness and ingenuity of this system, the beauty of its action, and the novelty of the forms and construction of the whole of the mechanism, excited so much admiration, that the whole of the machinery in Portsmouth dockyard has usually been popularly ascribed to Mr. Brunel alone. It must not be forgotten, however, that much machinery for the performance of isolated operations had been previously employed, as well by Mr. Taylor of Southampton, the contractor for the blocks of the navy previously to 1807, as by General Bentham himself in the dockyards.

At this distance of time it would be impossible to discover the exact shares of merit and invention that belong to Brunel, Bentham, and Maudslay, in this great work. To the first we may, however, assign the

1) Bentham's patents. "Repertory of Arts," vol. v. p. 293, and vol. x. pp. 221, 293, 367; also Memoir, by Mrs. Bentham, in Weale's "Quarterly Papers on Engineering," vol. vi.

merit of completing and organising a system of machine-tools, so connected in series, that each in turn should take up the work from a previous one and carry it on another step towards completion, so that the attendant should merely carry away the work delivered from one machine and place it in the next, finally receiving it complete from the last.

Some of the individual machines in the series had, it is true, been previously contrived and employed. Thus, *the self-acting morticing-machine* is distinctly described in Bentham's specification of 1793, so completely as to entitle him to the full credit of the invention of morticing-machines, whether by the process of boring a hole first and then elongating it by a chisel travelling up and down vertically, or by the process of causing the hole to be elongated by the rotation of the boring bit during the travelling of the work. The same specification describes boring-machines, some of which are similar in their arrangements to those of the block series; also the tubular gouge which is employed in the shaping-machine, and the formation of recesses, by a revolving and travelling tool, for the inlaying of the *coaks*.

That most useful machine-tool the *circular saw*, was introduced into this country about 1790; but "where, or by whom, the wood-cutter's saw was put into the form of a revolving disc, has not been recorded." Bentham greatly contributed to the practical arrangements necessary to give it a convenient form, such as the bench, with the slit, parallel guide, and sliding bevil-guide. Brunel also introduced various new arrangements, as also the mode of making large circular saws of many pieces. The origin of the engineer's *planing-machine* is not known; "it made its way into the engineering world silently and unnoticed, and some years afterwards, when its utility became recognised, and men began to inquire into its history, various claimants to the honour of its invention were put forward: we can only learn, that somewhere about 1820 or 1821, a machine of this kind was made by several engineers." As to the *turning-lathe*, Willis states that its origin is lost in the shades of antiquity, and that "the saw-mill with a complete self-action, turned by a water-wheel, is represented in a MS. of the 13th century at Paris, and is probably of much earlier contrivance."

It would be unjust even in this slight notice to omit to mention the important influence which Mr. Babbage's calculating machine has had in cultivating that high degree of mechanical skill required in the production of machine-tools. The novelty of form, the precision of workmanship, and the frequent repetition of similar parts in the calculating machine, led at almost every step to the necessity for inventing new tools, new lathe adjustments, and new combinations of well-known appliances, and all this under the inventive genius and eminent skill of Mr. Babbage, who had to educate his workmen to a high standard before they could comprehend, far less execute, his varied designs. Hence, Mr. Babbage's workshops became a school, in which such men as Clement and Whitworth studied; by whose influence and example our Engineering workshops received a fresh stimulus, and proved themselves capable of gaining still more brilliant victories of mind over matter than they had done under the generalships of Bramah, Watt, Bentham, and Brunel. In proof of this we need only refer to our Railway System, and the Tubular Bridge.

Hence, we may be well assured that the 17,000*l.* of the public money expended on the small fragment of the calculating machine which is now in the museum of King's College, (and which ought to have been sent by the proper authorities to the Great Exhibition,) were not expended in vain. In lately going over Mr. Babbage's workshops in company with their illustrious owner, and seeing the long-neglected forges, lathes, carpenters' benches, &c., together with huge piles of exquisitely wrought and adjusted organs of what were once intended to enter into the construction of the calculating machine, we could not but feel that the Great Exhibition must have soothed and satisfied Mr. Babbage with the thought that the study and labour of years, together with the amount of private fortune expended by him in the public service, were largely instrumental in accomplishing those glorious results which made England preeminent in the department of Machinery.

Whitworth & Co. of Manchester exhibited a splendid series of machine-tools. In their large lathe a novelty was introduced—viz. a cutting-tool at the back of the lathe, opposite the tool in front, the two tools being in inverted positions to each other. By this duplex arrangement the strain usually thrown by the cutters against the shaft is balanced, more correct work is produced, and in less time than in the ordinary lathe. Fig. LXVI. represents a transverse section of the lathe-bed, with the standards removed, with certain portions of the slide-rests also in section. A is the lathe-bed, B the guide-screw, and C the bottom slide-rest

or carriage, upon which is carried the compound top slide-rest D, in front of the lathe. A corresponding compound slide-rest E is similarly fitted on the back of the lathe; and it is this addition which constitutes the new feature in the lathe. The two slides are moved simultaneously in and out by the right-and-left-threaded screw-spindle F, so that the back and front tools G are taken in and out of cut upon the work H simultaneously. In another arrangement, two pair of cutting-tools are used, capable of being worked separately or simultaneously: the bed is of great length, of one casting, and may be used for two distinct lathes by employing an extra set of head-stocks. This lathe is chiefly employed for turning long shafting. In sliding a shaft, the two series of tools commence in the middle of its length, and proceed in a direction right and left. In the large lathe for turning railway-wheels, the duplex principle was also introduced, four cutting-tools being employed, two acting upon opposite sides of each wheel. There are two head-stocks, each driven independently, so as to avoid all torsion of the axle in which they are fixed; and the slide-rests admit of being easily removed in getting the wheels into or out of the lathe. Two other machines exhibited by Whitworth were self-acting planing, shaping, slotting, drilling, and boring machines, of great beauty and power; also machines for punching and shearing, for wheel-cutting and dividing, for shaping bolt-heads and nuts, &c. There were four planing-machines, differently arranged according to their applications. One was furnished with a reversing tool to plane both ways, and called, from its peculiar motion, a *Jim Crow machine*. The table is moved end-ways by a quick-threaded screw, which allows the driving motion to be removed from the middle to the end, where it is much more convenient. This machine is adapted for horizontal, vertical, or angular motions. The second planing machine has a fixed tool, and the return stroke of the table when not cutting is made much quicker than the forward or cutting stroke. The tool is fitted with a worm segment for shaping internal curves. A third is a crank-planing machine, with a quick return motion, obtained by making the crank-pin work in a hinged lever, with a joint below so arranged that while the cut is being made, the pin is working in the long rod of the lever, near the point at which it is connected with the table; but when the return motion is made, the pin is working in the lower part of the lever, much nearer the hinge, and thus is throwing the top end and the connecting-rod at a much greater rate. Through the kindness of a friend connected with this class of the Great Exhibition, we are enabled to lay before our readers the principle of this beautiful machine.

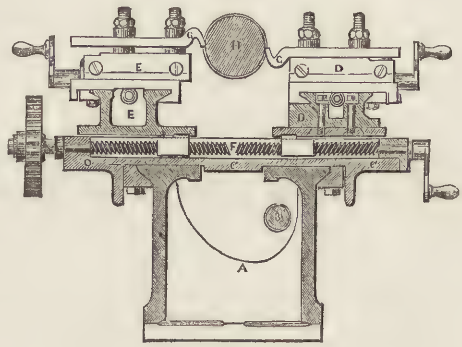


Fig. LXVI.

The disc-wheel A, Figs. LXVII. LXVIII. is driven by the pinion B, placed on the shaft of the driving pulley. This wheel carries a stout pin D projecting from one side, which pin works in a long slot in the arm C E, turning on a centre at C, and having the rod K at its upper end connected with the table or bed of the planing machine. Then, as the wheel A revolves, the arm C E will have an oscillating or to and fro motion about its centre, and the rod K will carry the table bearing the work to be planed to and fro under the cutting tool. But the two movements will be made in very different times, for it will be seen on reference to the dotted figure, that the pin revolves through the arc *g h d*, or $\frac{2}{3}$ of the entire circumference, while the arm moves from *f* to *e*, but that it revolves only through *d l g*, or $\frac{1}{3}$ of the circumference, while the arm returns from *e* to *f*. The cut is made by the tool during the motion from *f* to *e*, when the table moves slowly, and the pin being near the end of the lever arm C E is impelling the arm at the greatest mechanical advantage. But during the return stroke, when no work is to be done, the pin is working in the lower part of the slot, so as to shift the table rapidly back into a position to begin the next cut. In fact, it is obvious, that in the case sketched $\frac{2}{3}$ of the power applied is used in doing the actual work, and $\frac{1}{3}$ in moving the table back,

whereas, had the table been moved by a connecting rod applied directly from the pin F, ½ only of the power would have been used in doing work, and ½ employed only to slide back the bed.

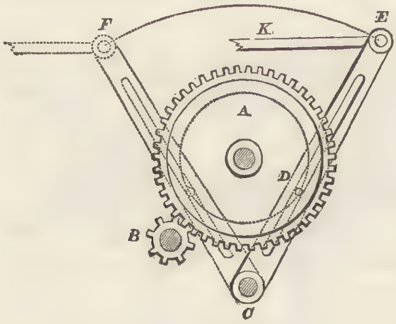


Fig. LXVII.

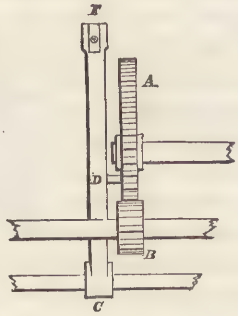


Fig. LXVIII.

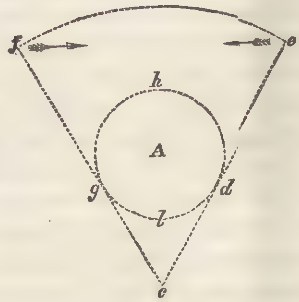
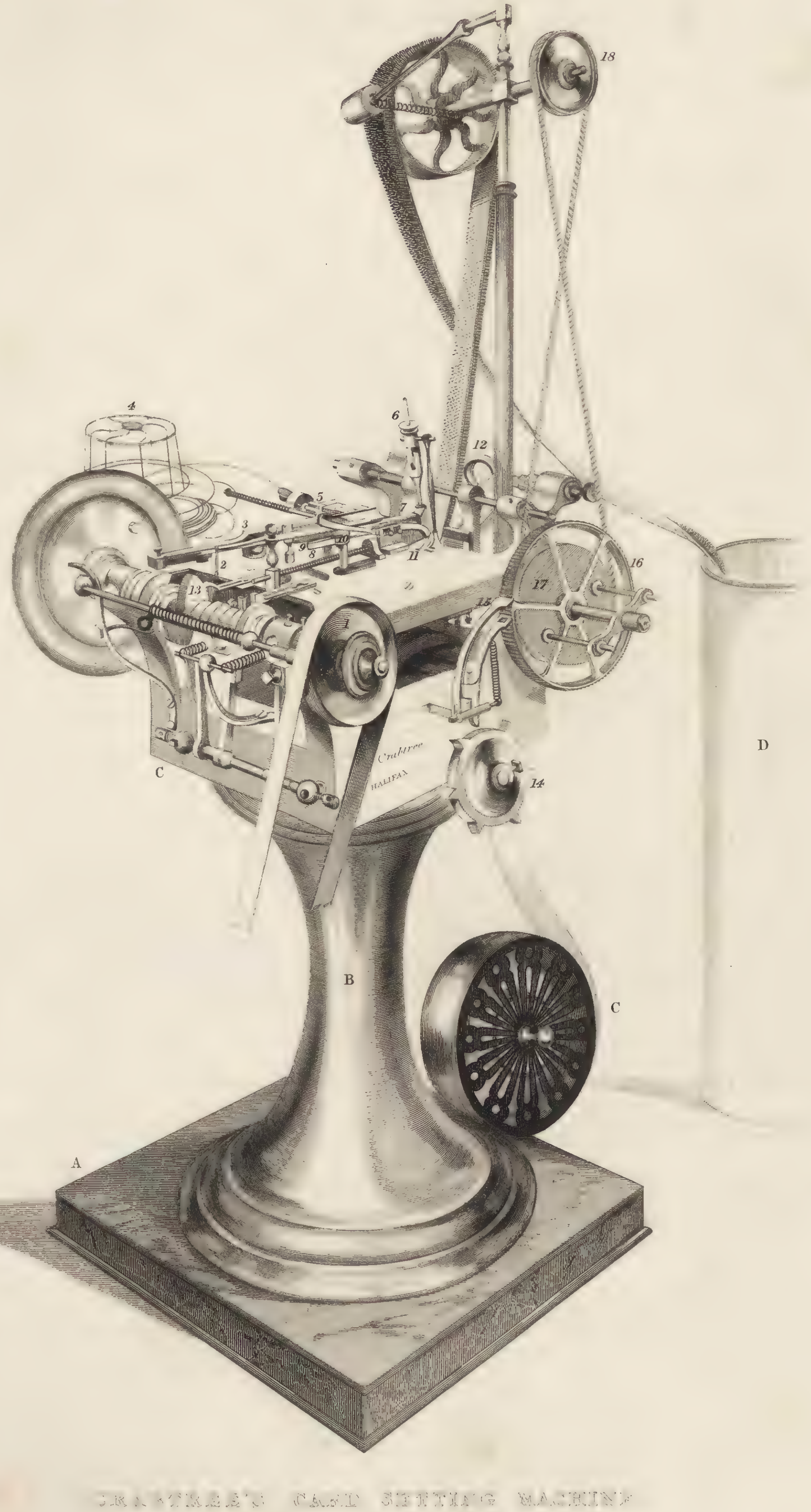


Fig. LXIX.

Mr. Whitworth also exhibited a shaping-machine adapted to flat, vertical, angular, circular, and hollow curved work; drilling machines,—one a radial drill of large size and great power. We must also refer to the powerful self-acting planing machine exhibited by Sharp Brothers, of Manchester, and to their large lathe for turning railway-wheels, and other objects of great weight and large diameter. It is scarcely an exaggeration to state that the elegant turning-lathe exhibited by Holtzapffel, with all its costly and luxurious additions and appliances, adapted to the most variegated and delicate work of the amateur, is not more precise in its results than the huge Manchester machines to which we have been referring.

Of the machines in motion, the most complete and impressive series was that contributed by Messrs. Hibbert, Platt & Co. of Oldham, for illustrating the various operations of preparing and spinning cotton. In the first operation, that of opening the entangled locks, and partially freeing the fibres from extraneous substances, a new apparatus, of American origin, was shown, in which the cotton as it comes from the bale is spread upon an endless apron, which carries it forward and delivers it to the machine, where it is drawn in between spiked and fluted rollers which loosen the matted fibres by a drawing action, instead of by the rapidly revolving beater, shown in Fig. 635 in our article COTTON; and the impurities are separated by the rotation of other fluted rollers, which revolve against the fibres as they are held by the spikes. There is also an improvement in the arrangement of the exhausting apparatus, the opened locks being made to pass over instead of under it, so that the dust removed by the draft is not allowed to pass through the sheet of lap.

Of carding engines a considerable number was exhibited; and near them was the beautiful machine employed in setting the wires or teeth into the cards which perform the work of carding. Mr. Crabtree, of Godby, near Halifax, the exhibitor, permitted us to take a copy of this apparatus, which is represented in the accompanying steel engraving. In our article COTTON, page 454, the general mode of action of this machine has been described; by reading that notice in conjunction with the following statement of the different parts, the reader will gain a tolerably correct idea of this ingenious contrivance. The working parts are mounted upon a firm base A and pedestal B of cast-iron, and the card fillet which is to be set with teeth is wound upon a feed-roller C; the other C refers to the square frame which contains all the motions. 1 is the driving-pulley on the tappit shaft, which conveys all the required motions. 2 is a stopper by which the attendant can stop the machine when a wire becomes crooked or broken, or the wire-holder, 4, is exhausted of its supply; 3 the feed-leaves, which take in a proper supply of wire; 5, knives that cut the wire into short lengths; 6, 7, 8, mouth-piece, crown, and tongue, which hold the wire until the two fingers 9 and 10 bend and form the staple, and carry it into the holes in the fillet made by 11, the pricker. 12 is the crooker which bends the staple, and forms the tooth after being put into the fillet. 13 is the cam-wheel, the form and arrangement of which determines the pattern of the card; 14 the notch-wheel, which gives motion to the taking-up catch; 15 the holding-catch, that holds 16, the brass wheel which takes



CRABTREE'S CARD SETTING MACHINE.

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vol 1

up the card when the teeth are put in, and gives the degree of fineness or coarseness of the card, according to the number of teeth in the wheel. 17 is the pulley giving motion to 18, another pulley, that takes the finished card over, and passes it into the drum D.

The carding machines, and the operation of carding, are described in our article COTTON. In the machines exhibited, the breaker card having done its work, the loose sliver was made to pass through revolving surfaces, which carried it round, and deposited it in circles in a can placed below for its reception; this can was made to revolve upon a centre excentric to the centre of motion of the delivering surfaces, thereby causing the sliver to arrange itself in a series of coils throughout the area of the can; as the can became filled, the sliver rose against a plate at the top, and as the operation proceeded, was pressed down and the coils condensed. By this means the cans are made to contain a much larger quantity than by the old method of a rising and falling plunger. A number of cans being thus filled, were taken to a machine in which a pair of rollers drew out 30 or 40 slivers, and wound them side by side upon an axle, so as to form a lap, which served to feed the finisher card, so slowly, however, that the sliver removed from the doffer was equal to only one of the slivers which entered.

The next machine, the drawing-frame, was furnished with a stop-motion, for stopping the machine on the breakage of a sliver. This was done by causing the slivers from the finishing carding engine to pass over weighted guide-levers, termed *spoons*, mounted so as to be capable of turning upon centres, and kept in a certain position by the tension of the slivers in the process of being drawn. Should one of the slivers break, or a can become empty, the spoon falls, and a part projecting from its under side intercepts the motion of a vibrating bar, and this acts upon other apparatus which shifts the driving-strap from the fast to the loose pulley. In the drawing-frame exhibited by Messrs. Parr, Curtis & Madely, the stop-motion is arranged differently; "the lower part is formed as a fork, and under the space between the prongs stands out a projection from the vibrating shaft, which, when arrested in its movement, causes the stoppage of the machine. The spoons, held up by the passing silver, fall vertically when a breakage takes place, and thereby intercept the vibrating projection with one or other of their prongs, and consequently arrest the motion of the machine."

The slubbing and roving-frames are described in our article COTTON. The improvements which have taken place of late years in these beautiful machines have been directed to increasing their producing power, the limit to which had previously been the velocity at which the revolving spindles and their flyers could be driven. In the machines exhibited by Hibbert & Platt, "the desired end is sought to be accomplished in two ways:—first, by reducing the top of the flyer, so as to enable the bobbin to traverse higher than usual, and thus avoid the necessity of carrying the flyer legs so far downwards; which, being thus reduced in length, will admit of being driven at a higher speed without increasing the vibration. The second method is by placing the bevil-pinion which drives the bobbin upon a fixed socket, instead of upon the spindle; by which method the vibration and the wear of the spindle is diminished. These improvements are said to enable the manufacturer to increase the driving speed of the spindles one-fifth beyond the ordinary velocity attained." In the slubbing and roving-frames exhibited by Mr. John Mason, of Rochdale, the increased velocity of the spindles is attained by "firmly attaching to the copping-rail, tubes, over which the bobbins pass, they being hollowed out sufficiently large for that purpose. The spindles pass through the tubes, and run in contact with the internal periphery thereof at top and bottom; by which arrangement two bearings are obtained a considerable distance apart, affording a support productive of great steadiness of action. It is stated that with the application of this arrangement, the spindles of roving-machines, where the lift of the bobbin is 6 or 7 inches, may make from 1,200 to 1,400 revolutions per minute." In the roving-frame of Messrs. Higgins & Sons, of Salford, the spindles, instead of being of the same diameter throughout the upper part of their length, as is usually the case, "are formed of varying diameters, decreasing towards the top, which configuration admits of their being driven at a greatly increased velocity without an extended vibration; the flyers also are so attached that the bobbin may traverse to a higher point than usual; and thus the legs are decreased in length, and consequently reduced in weight, possessing, at the

same time, stiffness which will bear an increased rate of revolution. The conical pulley is mounted upon a frame which swings upon centres, so that, at whatever diameter the strap may be situated, it will always be distended."

The slubbing-frame, and some of the other machines exhibited by Messrs. Parr, Curtis & Madely, were remarkably quiet in their action; so much so, as to excite the surprise of persons acquainted with the usual noise of a cotton-mill. This quiet action was produced by forming the toothed wheels which drive the bobbins of gutta percha,—an invention for which Messrs. Tatham & Cheetham have a patent. It remains, however, to be seen whether this material is capable of standing so much friction.

In the throstle exhibited by Messrs. Sharp Brothers, was a contrivance of American origin, termed the *ring and traveller;* that is, the yarn, instead of passing on to the bobbin through a flyer, is passed through a fine metallic loop, mounted so as to revolve upon a ring projecting from the copping rail. This loop is dragged round by the traction of the thread. The yarn is distributed upon the surface of the bobbin by the up and down motion of the ring, instead of the bobbin itself being made to rise and fall as is usual.

But perhaps the most admirable machines in this admirable series, were the *self-acting spinning mules;* machines in which the motions are complicated, and require to be performed with almost mathematical accuracy. Through the kindness of Mr. George Park Macindoe, we are able to give in two steel engravings the working parts of his exhibited mule, which, with the following description, will convey an accurate idea of this high result of the Machinist's art:—

Plate I. represents a side elevation of the mule headstock, with a transverse section of the carriage as nearly run in. Plate II. exhibits a corresponding plan of the mule-head, showing the end of the carriage next to it. The driving power is communicated to the machine through the horizontal first motion shaft, A, on which are the fast and loose strap pulleys, B, C. When the carriage is run in, up to the beam, or drawing-rollers, the front roller of which series is at D, the driving-strap is on the fast pulley, B, a portion of the strap's breadth being also on the loose pulley, C. Motion is communicated from the shaft A to the drawing rollers by the spur-wheel, E, gearing with a second wheel, F′, loose on a stud, carried by the frame, and gearing with a second carrier wheel, F. This wheel carries with it a small bevel-wheel, G, driving the bevel-wheel, H, on the horizontal shaft, I, connected to the front line of drawing-rollers. The spindles are also driven from the shaft, A, by the cord pulley, J, on the inner extremity of the shaft. From this pulley an endless band passes downwards and beneath the guide pulleys, K K, and thence to the front pulley, L, fast on the horizontal shaft, M, the opposite end of which carries the pulley, N. A band from the latter pulley, passing round the stationary pulley, O, in the head, drives the double grooved pulley, P, on a short vertical shaft, Q, in the carriage. The same shaft carries the bevel-wheel, R, gearing with the second wheel, S, the horizontal shaft of which carries the drums, or the cylinder, whichever is used for driving the spindles. Whilst these movements for the spindles and drawing-rollers are going on, the small pinion, T, on the shaft, I, drives the spur-wheel, V, on the shaft, W, carrying on its projecting end a scroll pulley, X. This pulley has the end of a band attached to and wound upon it, the loose end being passed round the guide pulley, Y, and then turned back and attached to the carriage at Z, for the purpose of traversing it outwards as the yarn is being spun.

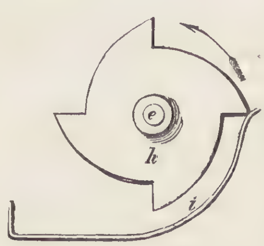


Fig. LXXI.

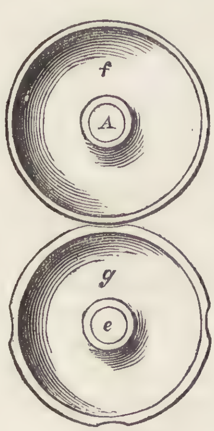
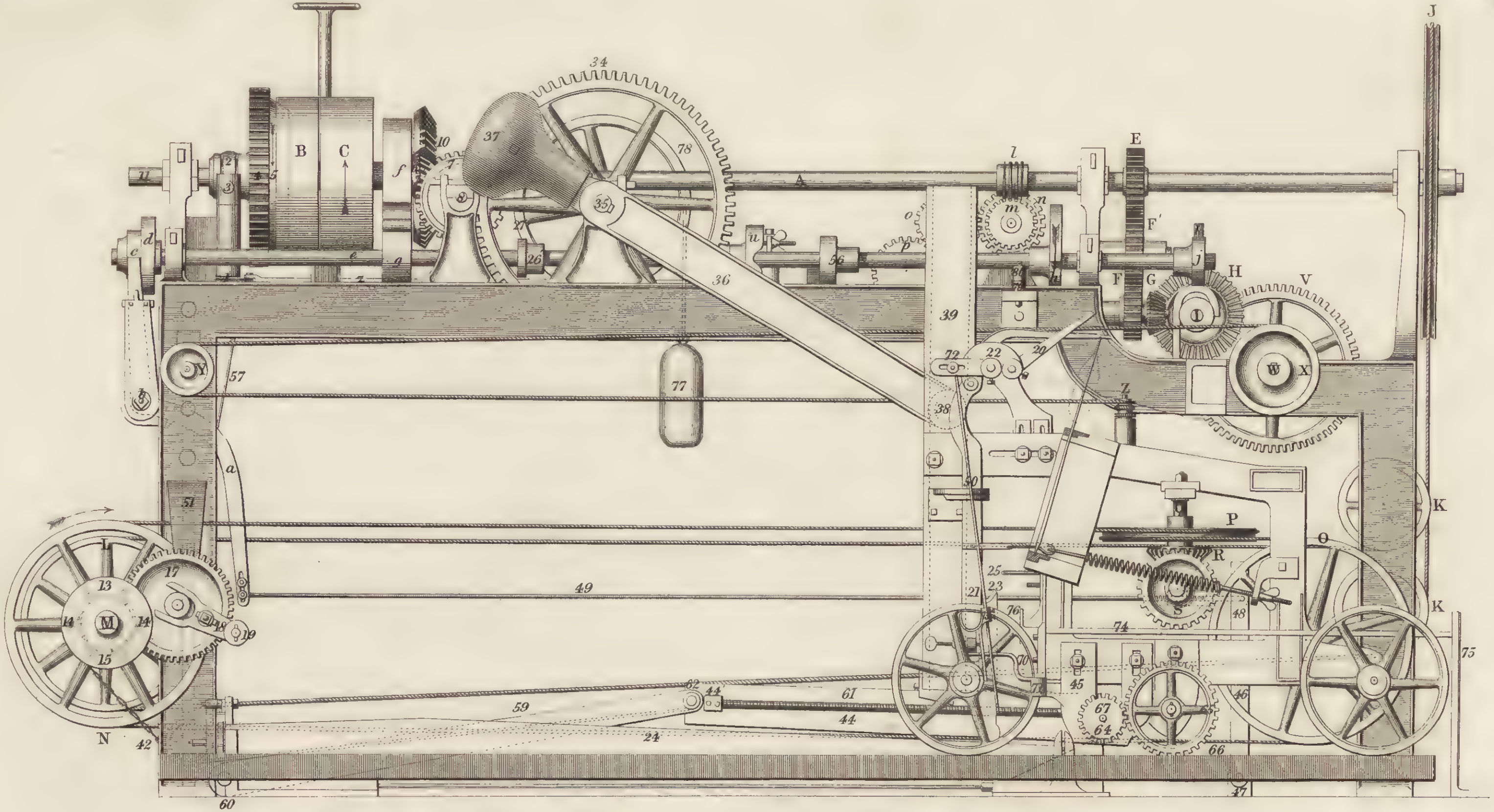


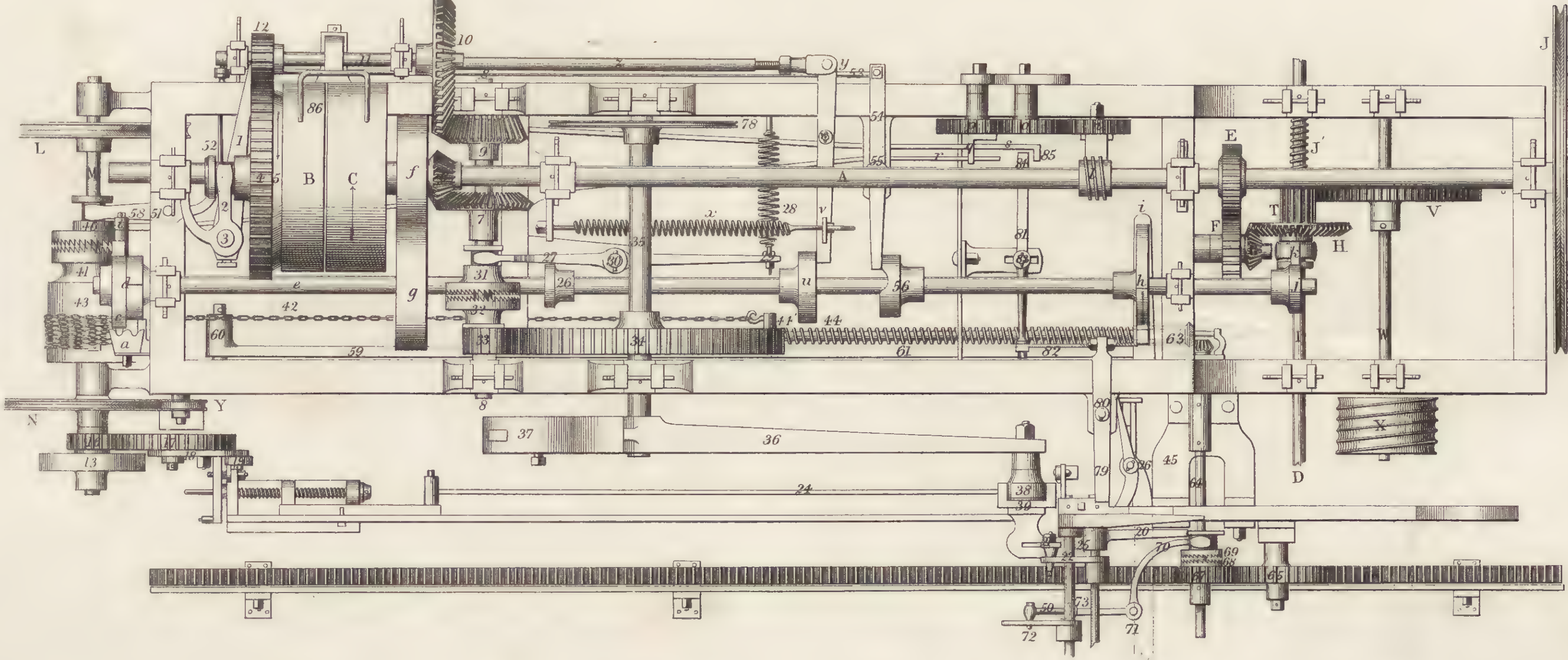
Fig. LXX.

When the carriage arrives at the extent of its stretch, that is, at its furthest point from the drawing-rollers, a stud or catch attached to the carriage comes in contact with the tail of the lever, *a*, pushing it outwards, so that as it turns on its fixed centre at *b*, its upper end comes directly beneath the projection, *c*, of the cam, *d*, on the horizontal shaft, *e*, being regulated as to its length of movement by a notched or indented spring-catch on its end. This cam is formed with four projections diametrically opposite to each other in two different planes. When the lever, *a*, is moved, its end is relieved from a projection at the part marked, *d;* and the shaft, *e*, then being released, makes a quarter of a revolution, and is again stopped by the projection, *c*, coming down upon the end of the lever. The partial revolution of the shaft, *e*, is effected by the revolving pulley, *f*, fast on the boss of the loose pulley, C, on the first motion shaft. The periphery of the pulley, *f*, is covered with leather, so as to be capable of driving the corresponding pulley, *g*, keyed on the cam shaft, *e*, which is extended to the front of the head-stock so as to afford facilities for carrying the set of cams. Both these pulleys, *f* and *g*, are represented in elevation in Fig. LXX. The lower one, *g*, is recessed on its periphery in four places diametrically opposite to each other, so that when any one of these recesses is turned towards the pulley, *f*, the leather surface of the latter works free of it. The cam shaft, *e*, also carries a quadruple cam, or ratchet of four teeth, *h*, as shown in Fig. LXXI. A flat spring, *i*, is screwed at one end to the frame, so that its opposite free end shall



MACINDOE'S SELF ACTING MULE. PLATE 1.

Copied by permission of the Patentee from the Machine exhibited at the Great Exhibition.



always press on one or other of the projections of the cam, *h;* thus tending to turn the cam round a short distance in the direction of the arrow—and consequently, when such a movement does take place, the recessed pulley, *g*, being keyed on the same shaft, receives the same movement. As the lever, *a*, is pushed back or forward from one plane of the cam, *d*, to the other, the cam shaft being released is then turned slightly round by the spring action upon the cam, *h*, until the recess in the pulley, *g*, which is, at the time being, nearest to the centre of the pulley, *f*, is passed onwards, until the plain portion of the former pulley comes in contact with the periphery of the latter. The revolution of the pulley, *f*, then carries round the pulley, *g*, a quarter of a revolution, until the next of the four recesses comes forward to break the connexion between the two pulleys.

As the carriage arrives at the extent of its stretch, the first movement performed by the cam shaft, *e*, actuated in the manner explained, is to throw the bevel-wheel, H, out of gear with the wheel, G, and thus stop the motion of the drawing rollers and carriage. This is accomplished by the cam, *j*, which in coming round presses against the projection on the upper end of the forked lever, *k*, working in a ring groove in the projecting boss of the wheel, H. This wheel slides loose on a feather in the shaft, I, and when otherwise unacted on, it is kept in gear with the wheel, G, by the pressure of the helical spring, J, which abuts at one end against the end-bearing of the shaft, the other end pressing against the outside of the boss of the spur pinion, T, placed loose on the shaft, immediately behind the bevel-wheel. The next operation is the stopping the motion of the spindles. This is effected by the worm, *l*, on the first motion shaft, A, gearing with the worm-wheel, *m*, keyed upon a short tubular shaft, carrying a spur-wheel, *n*, on its opposite end, and running loose on a short stud carried by the frame. The latter wheel again gears with the carrier wheel, *o*, driving a similar wheel, *p*, both wheels running loose on studs carried by the frame. A pin, *q*, is attached to the face of the wheel, *p*, and as the latter makes one revolution during each stretch of the carriage, this pin is adjusted to act at the proper time upon the ends of the rods, *r* and *s*. The end of the rod, *r*, is notched to give a hold to the revolving pin, *q*, which thus pushes the rod longitudinally, the opposite end of the latter being jointed at *t*, to an upright lever on a short shaft carrying the lever, *a*, holding the cam, *d*. Thus, the action of the revolving pin, *q*, is to effect the change of position of the lever, *a*, as before noticed, permitting the pulley, *g*, with its shaft, *e*, to make a quarter of a revolution, bringing the cam, *u*, into action to effect the backing. This cam is notched on one side, as shown in the elevation, Plate I, and the quarter revolution just described brings this notch opposite to the end of the lever, *v*, loose on a centre at *w*. When the end of the lever, *v*, falls into the notch into which it is pressed by the helical spring, *x*, the movement of the opposite end, *y*, of the lever, draws the rod, *z*, in the direction of the arrow. The other end of this rod is jointed to the end of the horizontal lever, 1, which is connected to the forked lever, 2, set on a centre at 3. The forked end of this lever fits to the grooved ring on the boss of the spur-wheel, 4, which is in one piece with the conical friction pulley, 5, and the latter is thus moved into frictional contact with the internal cone of the fast pulley, B, on the first motion shaft, A. The wheel, 4, with its external cone, 5, is made to revolve in the direction of the arrow, by the bevel-wheel, 6, on the first motion shaft, A, gearing with the wheel, 7, on the transverse shaft, 8. This shaft again carries a bevel-wheel, 9, gearing with the large wheel, 10, on the longitudinal shaft, 11, the opposite end of which shaft carries a spur-pinion, 12, driving the wheel, 4, in a direction opposite to that of the first motion shaft. Thus, when the cones are brought into action, the motion of the pulley, B, with its shaft, A, is reversed, and this change of movement reverses the motion of the spindles. So soon as the backing commences, the band-pulley, N, revolves in the direction of the arrow, carrying round with it on the same shaft the disc, 13, and some of the detents in which, 14, hold with the teeth of the ratchet-wheel, 15, carrying it round in the same direction. This ratchet-wheel is attached to the spur-wheel, 16, both running loose on their shaft; and the latter drives the wheel, 17, having screwed to one side of it the adjustable lever, 18, carrying an anti-friction pulley, 19, on its free end. The upward movement of this lever then puts down the faller, 20, by elevating the pendant rod, 21, jointed at its upper end to the short lever, 22, working the faller. By the time the faller-wire has arrived at the level of the points of the cops, the foot of the rod, 21, is drawn upon the top of the catch, 23, resting on the shaper, 24. This movement of the rod, 21, then brings it against the end of the short lever, 25, set on a centre at 26. The opposite end of this lever comes in contact with the tail of the lever, *a*, shifting its upper end to the other plane of the catches—thus allowing the cam shaft to make a third quarter of a revolution. This movement then forces the end of the lever, *v*, out of the side notch of the cam, *u*, disengaging the cone, 5, from the pulley, B, and the movement of the cam, 26′; then releasing the forked lever, 27, the helical spring, 28, attached to the frame, pulls back the end, 29, of this lever, turning it upon its centre, 30, so as to force the sliding-clutch, 31, which is set on a fixed feather on the shaft, 8, into gear, with its loose counterpart, 32, on the same shaft. The spur-pinion, 33, is then carried round with its shaft, driving the large wheel, 34, keyed on the transverse shaft, 35. This shaft projects beyond the front of the framing, and carries the long oscillating or vibrating lever, 36, the weight of the lower portion of which is counterbalanced by the weight, 37. The lower end of this lever carries an anti-friction pulley, 38, which is fitted to work in the vertical slot of the upright bar, 39, fast on the front end corner of the carriage; and thus a semi-revolution, or a portion thereof, of this radial arm, puts up the carriage in an expeditious and simple manner. At the same moment that the clutches, 31 and 32, are engaged, the clutches, 40 and 41, on the shaft, M, are also put in gear to wind on the yarn, by uncoiling the chain, 42, from the barrel, 43. One end of this chain is fast to the barrel, and being wound upon it, the loose end is attached to a hook, carried by the adjustable nut, 44′, of the screw, 44, which is connected to the end of the carriage by the bracket, 45. Thus, as the carriage recedes from the chain-barrel, 43, during the putting-up movement, motion is communicated to the spindles by the band-pulley, N, carried on the shaft, M, along with the barrel, 43; which latter is caused to revolve by the carriage drawing off the chain.

When the carriage arrives at the beam, the bracket, 45, comes against the lower part of the upright lever, 46, which turns upon a fixed centre on the floor, at 47. This movement then forces back the lever, the upper end of which being jointed at 48 to the rod 49, attached at the opposite end to the tail of the lever, *a*, draws back the latter, and shifts the catch-end to the other plane of the cam, *d*, allowing the shaft, *e*, to make its fourth quarter revolution, completing the series of movements of the cam apparatus.

The last shift of the cam shaft disengages the two sets of clutches, 31 and 32, and 40 and 41, and sets the rod, 50, in readiness for another stretch. The clutches 40 and 41 are worked from the upright shaft, 51, the head of which carries a bent lever, 52, jointed to the rod, 53, the opposite end of this rod being connected to the lever, 54, moving on a fixed centre at 55. This lever is worked by the notched cam, 56, which acts in a manner precisely similar to that of the cam, *u*, a spring being placed at 57, to press upon the bent lever arm for the return movement of the sliding-clutch, worked by the forked lever, 58, carried on the same upright shaft, 51.

In connexion with the copping motion, a lever, 59, acting as a counterpart to the radial arm of the screw, 44, is jointed to a stud on the floor at 60. As the carriage recedes from the drawing rollers, the outward movement of the radial arm, 61, causes a knee-joint action at 62, where the lever, 59, is connected, and the latter serves to carry up the radial arm, so as to make it assume a nearly vertical position, when the stretch is completed. The radial arm and screw action in self-acting mules is of the ordinary kind, except in as far as regards the mode adopted for working the nut, 44′, up the screw in the radial arm, as the diameter of the cop increases. When the building of the cop commences, the nut, 44′, stands at the bottom of the screw, next the carriage. This extremity of the screw carries a bevel-pinion, 63, gearing with a similar pinion fast on the shaft, 64, working in a bearing in the bracket, 45,—a small spur-wheel, 65, runs loose on a stud in the headstock frame, and gears with the fixed rack, 66, on the floor, as also with the pinion, 67, loose on the shaft, 64, and carrying with it the loose clutch, 68. The counterpart of this clutch, 69, slides on a feather in the shaft, being worked by the curved end of the forked lever, 70, oscillating on a fixed stud centre, 71. The rod, 50, attached at 72, to the back lever of the counter-faller, carries a stud-piece, 73, in which is cut a diagonal slot, to allow the angular end of the forked lever, 70, to pass through it. With this arrangement, when the aggregate threads of yarn get too tight in winding on, the counter-faller is depressed, and the clutches, 68 and 69, are put into gear by their actuating lever, thus causing the revolution of the screw in the radial arm, by means of the bevel-pinions, 63, worked by the shaft 64, to work the nut 44′, upwards, until the yarn is so much slackened as to permit the counter-faller to rise again, and disengage the clutches.

When the carriage arrives at the drawing-rollers, in the putting-up motion, the faller is disengaged by the sliding rod, 74, which is carried in guides in the carriage. This rod, coming in contact with the fixed upright 75, its opposite end, 76, pushes against the end of the rod, 21, disengaging it from the piece, 23, when the faller rises by the downward tension and momentum of the rod. During the outward stretch of the carriage, the lever is returned outwards by the counter-weight, 77, which is hung to a chain passed over the pulley, 78, on the lever-shaft. When the carriage has been put up, and has arrived within two or three inches of the roller-beam, the upright slotted piece, 39, comes in contact with the lever, 79, moving on a centre at 80. The opposite end of this lever is jointed to the lever, 81, by the link, 82,—the lever, 81, moves on a centre at 83, and its contrary end, 84, hits the angular projection on the end of the rod, 85, and shifts the strap-fork, 86, to the fast pulley, B, for the commencement of a new stretch.

We cannot close this brief account of the cotton machinery of the Great Exhibition, without referring to the specimens of cotton yarn spun and exhibited by Mr. Houldsworth of Manchester, which were truly marvellous. Some of the specimens of fine cotton yarn, cross-reeled and in hank, were from No. 100 to No. 2,150 : that is, each of these and the intermediate numbers indicates the number of hanks to the pound weight of 7,000 grains, each hank measuring 840 yards. 1 lb. weight of No. 2,150 extends upwards of 1,000 miles in length. The following were the labels to the specimens exhibited :—

No. 100 single cotton yarn, 1 Hank of 840 yards weighs	70 grains.
200	35
300	23·3
400	17·5
500	14
600	11·6
700	10

The fineness of *lace thread*, which is formed by doubling two yarns, is expressed by the number of hanks in 2 lbs. weight of 14,000 grains. 1 lb. weight of No. 670, extends 160 miles :—

No. 100 doubled yarn or lace thread, 1 Hank of 840 yards weighs	140 grains
200	70
300	46·6
400	35
500	28
600	23·3
670	20·9

The more important manufacturing machines concerned in the preparation of Flax exhibited in the Great Exhibition, are noticed in our article on that subject. We must also refer to Silk and Wool for notices of the important machines in those sections, and to Weaving for an account of the various looms. Weaving in great variety, in cotton, flax, silk, worsted, and wool, was illustrated in the Exhibition. A power-loom, made in 1798 or 1800, was placed, by way of contrast, by the side of the most improved loom of the present day. The old machine

could be worked to advantage at 60 picks per minute, requiring the attendance of one person to each loom, or five persons to six looms. The modern looms can be driven at 220 picks per minute, the rate at which they were made to work in the Exhibition, and in all the best power-loom mills of this country. One person can attend two, and in some cases, three looms, and in a work of 60 hours, can produce 26 pieces of printing cloth, 25 inches wide, 29 yards long, and 11 picks per $\frac{1}{4}$ inch. The cost of weaving each piece is $5\frac{1}{8}d.$ On the old power loom, one operative could produce only 4 pieces, and at a cost of 2*s.* 9*d.* each.

The *steam-engine* by which this and so much other wonderful service was performed, was not well represented in the Exhibition, and the reasons for the omission have been explained by Mr. Hensman. A factory-engine is of large size and weight, and requires strong foundations, and abundance of steam and water if at work, and if not, its performance cannot be judged of. Six-horse power was the limit put upon the size of engines that were to be set in motion at the Great Exhibition; and as engines of this size are made by almost every engineer, the leading makers, whose celebrity causes them to obtain orders for the more costly large engines, seldom trouble themselves about either making or improving small ones, and did not send any of their large ones. Models of stationary engines were exhibited, both reciprocating and oscillating. Several small rotatory engines were exhibited at work, illustrating the excentric cylinder, the revolving diaphragm, and the disc principles. *Marine engines*, on account of their great bulk and weight, were not numerous; but those which were exhibited were of very superior description. The firm of James Watt & Co. sent a pair of screw-propeller engines of 700 horse-power, and weighing, without the boilers, more than 100 tons. Marine oscillating engines for paddle-wheel boats were shown in a model by two of the first English makers, Maudslay, Sons & Field, and Mr. Penn of Greenwich,[1] the latter of whom also sent a pair of 12-horse engines as used in the boats on the Thames. A pair of full-sized 70-horse boat engines were sent from Belgium by Cockerell of Liege. In reference to some of these engines, Professor Gordon remarks:—"In viewing these engines, we have our attention forcibly drawn to the connexion of the mechanical arts. Advances in the manufacture of iron and in tool-making were essential to the production of such engines as we here see. It would have been scarcely possible for Watt to have produced such engines, excepting at an expense disproportioned to their commercial value. The manufacture of malleable iron has improved, so that now pieces of a weight and form are forged in ordinary routine which twenty-five years ago were considered as impossible, or only singular *tours de force*. The slide principle in tools has given a power of producing perfection of fit and finish which the most skilful hands could not approach to not more than thirty years ago." Our increased facilities for the production of large engineering works, is also well illustrated by the rapid increase of steam-boats. In 1814 there were only seven steam-vessels in Great Britain. In 1845 there were 1,500, and at the present time there are upwards of 2,000.

The *locomotive engines* of the Exhibition were not of the ordinary description, such as are employed upon the railways of this and other countries, but of an exceptional kind, such as *tank-engines*, which have no tenders, and are seldom used except for short lines. The numerous narrow-gauge engines made by Sharp Brothers, and others, and the usual description, as made by Stephenson, were not represented on the English side. The broad-gauge engines were well illustrated by the noble locomotive sent by the Great Western Company, which required only a drink of water and a feed of coke to exert a force equal to that of 1,000 horses! A striking example of the value of steam as applied to locomotion.

The *railway carriages* exhibited by the Great Northern Railway Company illustrated the use of teak-wood, which requires no paint, but only a coat of varnish; and in Mr. Haddan's carriages, the panels were of papier-maché instead of wood, and the mode of framing without grooves prevented the wet from getting into the joints. *Railway wheels* and *axles* were very numerous, among which we must notice Brigg's compound tires with hard iron in the wearing part, and tough in the other parts. The cast-iron wheels in common use in America were

(1) The models exhibited by these firms excited general admiration, on account of the perfection of their proportions and workmanship, the delicacy of the working parts, the beauty of their finish, and their miniature resemblance to the originals.

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No. 100	single cotton yarn, 1 Hank of 840 yards weighs	70 grains.
200	....	35
300	....	23·3
400	....	17·5
500	....	14
600	....	11·6
700	....	10

The fineness of *lace thread,* which is formed by doubling two yarns, is expressed by the number of hanks in 2 lbs. weight of 14,000 grains. 1 lb. weight of No. 670, extends 160 miles :—

No. 100	doubled yarn or lace thread, 1 Hank of 840 yards weighs	140 grains
200	....	70
300	....	46·6
400	....	35
500	....	28
600	....	23·3
670	....	20·9

The more important manufacturing machines concerned in the preparation of FLAX exhibited in the Great Exhibition, are noticed in our article on that subject. We must also refer to SILK and WOOL for notices of the important machines in those sections, and to WEAVING for an account of the various looms. Weaving in great variety, in cotton, flax, silk, worsted, and wool, was illustrated in the Exhibition. A power-loom, made in 1798 or 1800, was placed, by way of contrast, by the side of the most improved loom of the present day. The old machine

could be worked to advantage at 60 picks per minute, requiring the attendance of one person to each loom, or five persons to six looms. The modern looms can be driven at 220 picks per minute, the rate at which they were made to work in the Exhibition, and in all the best power-loom mills of this country. One person can attend two, and in some cases, three looms, and in a work of 60 hours, can produce 26 pieces of printing cloth, 25 inches wide, 29 yards long, and 11 picks per $\frac{1}{4}$ inch. The cost of weaving each piece is $5\frac{1}{8}d.$ On the old power loom, one operative could produce only 4 pieces, and at a cost of $2s.$ $9d.$ each.

The *steam-engine* by which this and so much other wonderful service was performed, was not well represented in the Exhibition, and the reasons for the omission have been explained by Mr. Hensman. A factory-engine is of large size and weight, and requires strong foundations, and abundance of steam and water if at work, and if not, its performance cannot be judged of. Six-horse power was the limit put upon the size of engines that were to be set in motion at the Great Exhibition; and as engines of this size are made by almost every engineer, the leading makers, whose celebrity causes them to obtain orders for the more costly large engines, seldom trouble themselves about either making or improving small ones, and did not send any of their large ones. Models of stationary engines were exhibited, both reciprocating and oscillating. Several small rotatory engines were exhibited at work, illustrating the excentric cylinder, the revolving diaphragm, and the disc principles. *Marine engines*, on account of their great bulk and weight, were not numerous; but those which were exhibited were of very superior description. The firm of James Watt & Co. sent a pair of screw-propeller engines of 700 horse-power, and weighing, without the boilers, more than 100 tons. Marine oscillating engines for paddle-wheel boats were shown in a model by two of the first English makers, Maudslay, Sons & Field, and Mr. Penn of Greenwich,[1] the latter of whom also sent a pair of 12-horse engines as used in the boats on the Thames. A pair of full-sized 70-horse boat engines were sent from Belgium by Cockerell of Liege. In reference to some of these engines, Professor Gordon remarks:—"In viewing these engines, we have our attention forcibly drawn to the connexion of the mechanical arts. Advances in the manufacture of iron and in tool-making were essential to the production of such engines as we here see. It would have been scarcely possible for Watt to have produced such engines, excepting at an expense disproportioned to their commercial value. The manufacture of malleable iron has improved, so that now pieces of a weight and form are forged in ordinary routine which twenty-five years ago were considered as impossible, or only singular *tours de force*. The slide principle in tools has given a power of producing perfection of fit and finish which the most skilful hands could not approach to not more than thirty years ago." Our increased facilities for the production of large engineering works, is also well illustrated by the rapid increase of steam-boats. In 1814 there were only seven steam-vessels in Great Britain. In 1845 there were 1,500, and at the present time there are upwards of 2,000.

The *locomotive engines* of the Exhibition were not of the ordinary description, such as are employed upon the railways of this and other countries, but of an exceptional kind, such as *tank-engines*, which have no tenders, and are seldom used except for short lines. The numerous narrow-gauge engines made by Sharp Brothers, and others, and the usual description, as made by Stephenson, were not represented on the English side. The broad-gauge engines were well illustrated by the noble locomotive sent by the Great Western Company, which required only a drink of water and a feed of coke to exert a force equal to that of 1,000 horses! A striking example of the value of steam as applied to locomotion.

The *railway carriages* exhibited by the Great Northern Railway Company illustrated the use of teak-wood, which requires no paint, but only a coat of varnish; and in Mr. Haddan's carriages, the panels were of papier-maché instead of wood, and the mode of framing without grooves prevented the wet from getting into the joints. *Railway wheels* and *axles* were very numerous, among which we must notice Brigg's compound tires with hard iron in the wearing part, and tough in the other parts. The cast-iron wheels in common use in America were

(1) The models exhibited by these firms excited general admiration, on account of the perfection of their proportions and workmanship, the delicacy of the working parts, the beauty of their finish, and their miniature resemblance to the originals.

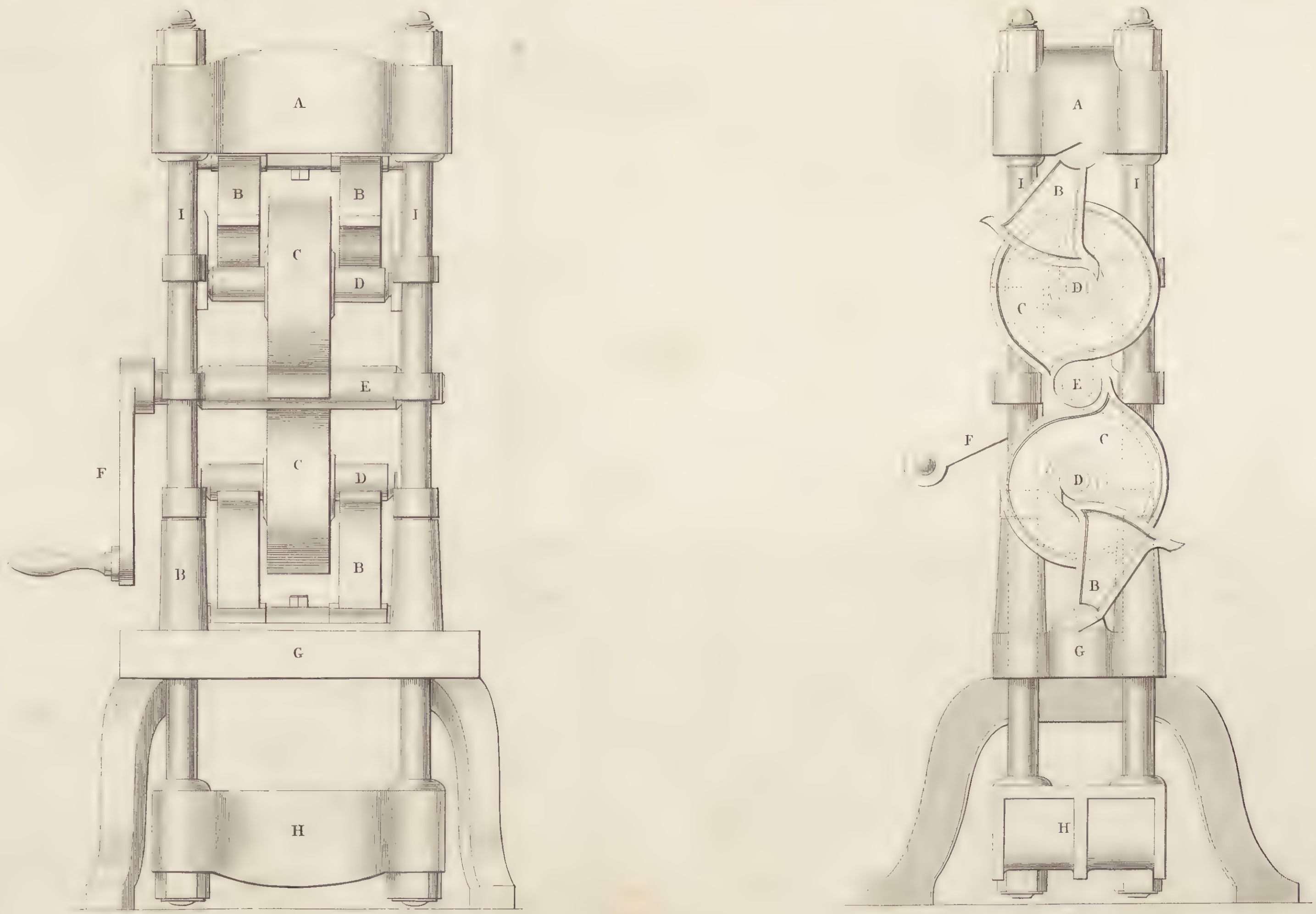
exhibited in the United States department, and we regret, with Mr. Hensman, "that no railway engines or models of carriages were sent from that country, as from the great differences that exist between them and those in use here, they would, when contrasted, very probably have shown advantages capable of mutual adaptation." A great variety of plans for the permanent way was exhibited, and the *rails* of the largest size and section showed the great capabilities of our iron works in producing rolled iron.

A few other examples of the application of steam remain to be noticed. Mr. Garrett exhibited a *steam-pump* of good construction. Messrs. M'Nicol & Vernon of Liverpool had a working model of their *steam travelling crane*, which excited much attention. It is stated that with one of these cranes, a boy may lift a weight of 10 tons or more, and traverse it either endways or sideways with the greatest facility. For large buildings, wharfs and docks, stone-yards or timber-yards, it promises to be a very valuable aid. Some idea of its powers may be gained from the fact, that one of these cranes has displaced two of the ordinary hand travelling cranes. The latter employed 4 men each, 3 men on the platform to hoist, &c. and 1 man below to fasten on the logs; in all, 8 men at 16*s.* per week each, or 332*l.* 16*s.* per annum. The steam crane is worked by a youth, at 10*s.* per week, and a man, who fastens the logs to the hooks or chains, at 16*s.* per week, or 67*l.* 12*s.* per annum; so that one machine not only effects a saving of 265*l.* 4*s.* per annum, but does the work of two cranes, which it displaced, and doing it in a much more efficient manner. [See CRANE.]

Although an amount of water-power represented by the power of 20,000 horses is employed in this country in our cotton, flax, wool, worsted, silk, paper, and iron works, in saw-mills, &c.; yet the construction of water-wheels and water-engines was not well illustrated in the Exhibition. Indeed, the only illustration of water-power, was a model of two enormous overshot wheels, erected by Mr. J. Smith at Wheal Friendship Mine in Devonshire. In the French department was a *turbine* on Fontaine's system of construction, said to be capable of doing a duty of 70 per cent. of the water used to set it in motion.

Machines for raising water, such as pumps, the hydraulic ram, the Archimedean screw, fire-engines, &c., are very numerous. The subject of centrifugal pumps led to much lively discussion, and afforded a valuable lesson as to the great effects to be produced by a very small noiseless machine, running at a high speed, instead of the old-fashioned cumbrous pumps, which make a few strokes per minute, and shake the earth near them at each stroke. As an example of this, Mr. Hensman cites the case of the ponderous machines constructed in this country a few years since for the purpose of draining the lake of Haarlem. The weight of the pumps and valves attached to one of these engines was between 100 and 200 tons, and they were adapted to raise 70 tons of water per minute a height of about 15 feet when working their usual speed of 8 or 10 strokes per minute. A centrifugal pump to do the same amount of work would weigh only about 2 tons. The most advantageous point of working for these small fast-running engines, is where the lift does not exceed 15 or 20 feet. In cases where the water is to be lifted any very great height, other pumps will perform better.

Printing-presses and *machines* were numerous on the English side, but we scarcely remember one in the foreign departments. The cylinder machine, as it left the hands of Professor Cowper many years ago, was shown in model, and although it is in almost universal use, its general form and arrangements have been but little altered. Mr. Applegarth's large vertical machine used for newspaper printing was fixed, and worked daily, to the admiration of crowds of visitors, who had an opportunity of seeing one of the most singular and remarkable sights of the age,—a machine throwing off 5,000 copies per hour of the *Illustrated London News.* For a more particular account of these and other presses, we must refer to the body of our work. There was, however, a press in the United States department of so remarkable a character, that it requires special notice in this place. We allude to Mr. Dick's anti-friction press, which was patented in America in October 1848, and is favourably noticed in the Eighth Annual Report of the American Institute of New York (1850). In its most extended form, this press consists of two eccentric or cam wheels C C, with a roller E between them. Motion is communicated to the cam wheels by the roller, which is put in motion by a lever F or a wheel



MR DAVID DICK'S ANTI-FRICTION PRESS.

Copied by permission of the Proprietor from the original Machine in the United States department of the Great Exhibition

attached to its axis, the friction being relieved by a pair of sectors supporting the axis of each cam wheel, which sectors revolve on an edge. A second modification, which adapts it to purposes not requiring much movement, consists simply of two eccentric or cam sectors, with a roller between put in motion by a lever or wheel as before, the moving members of both being preserved in their vertical position by slots or guides in the frame. In the accompanying steel engraving, the centre roller E is made to revolve by means of the winch or lever F, by which means the two cams C C are made to revolve in opposite directions upon their axis D D, and as these have their bearing on the face of the sectors B B, and as these are edge-shaped at their centre of motion, they move without friction, and hence the name of the press.

"It will be seen," says the Report, "that in this machine there are no rubbing surfaces, so that friction is overcome, and this has always been the great obstacle in the use of other machines, except the hydrostatic press, where intense power has been aimed at. Dick's arrangement may be termed the *rolling cam*. The hydrostatic press has hitherto been used for pressing and lifting, where intense force was required. In this press, the friction is converted from a variable, as it exists in other machines, to a constant quantity of resistance, or nearly so, under all intensities. Dick's press is in some respects superior to the hydrostatic: it is less costly, acts in quicker time, is more convenient to handle, is easy of construction, requires no oil to lubricate its parts, and no water to move it; it is also not liable to get out of order. The power of this machine was shown at the Navy Yard, Brooklyn, where one of them, 7 feet in height, was used for extracting the piles that had been driven in constructing the coffer-dam required for the Dry Dock. The piles had been driven into the ground about 40 feet; they were about 50 feet long, and 16 to 20 inches square, dowelled together and spiked, and some of them were secured to the adjoining piles by heavy iron bolts 2¼ inches diameter, and pressed together by tapering piles in the form of wedges. The power of the machine was shown in overcoming the adhesion of the moist ground, tearing the piles loose from the joinings by the dowelling and spikes, and breaking the heavy iron bolts; exerting, in fact, a lifting power of above 300 tons, with an applied force of from 4 to 6 hands. This machine is extensively used in America for straightening railroad iron, for pressing oils, paper, books, cotton, hemp, cloth, flax, tobacco, hay, &c.; for elevating ships in dock, for hauling out vessels on inclined planes, moving houses, extracting stumps, punching iron and other metallic plates, cutting off iron bars, shearing boiler plates, printing, coining, embossing, planishing tin plates, cutting out and pressing jeweller's work, &c."

In the engraving, A is the head-beam to the press, B B sectors relieving the friction of the journals of the cams C C, D D the cam journals, E E the centre wheel rolling between the cams C C, F F the crank or handle, G G the upper platin and base of the machinery, H H the bed or lower platin, I I rods connecting the machine. On using this arrangement as a press for crushing seeds, for example, the bag of seeds is placed on H; on turning the handle F, H is raised up towards G with enormous force, and with a very moderate exertion of power.

Several attempts to apply *electricity as a moving power* were exhibited. As this is a subject upon which many ingenious minds have been, and may be engaged, we think it important to submit to them the following simple calculations made by Liebig:—

With a simple flame of spirits of wine under a proper vessel containing boiling water, a small carriage of 200 to 300 lbs. weight can be put into motion, or a weight of 80 to 100 lbs. be raised to a height of 20 feet. The same effects may be produced by dissolving zinc in dilute sulphuric acid in a galvanic battery. Now, on inquiring which is the least expensive method, we must remind the reader that there are certain unalterable ratios, known as chemical equivalents, which are proportionate to each other, and may be expressed in numbers. Thus, if we require 8 lbs. of oxygen to produce a certain effect, and we wish to employ chlorine for the same effect, we must employ neither less nor more than 36 lbs. weight. In the same manner, 6 lbs. weight of coal are equivalent to 32 lbs. weight of zinc. When zinc is consumed in a galvanic battery, it is converted into an oxide, and dissolved by sulphuric acid, the consequence of which is the production of an electric current, which, if conducted through a wire, renders it magnetic. In thus effecting the solution of a pound weight of zinc, we obtain an amount of force adequate to raise a given weight 1 inch, and to keep it suspended; and the amount of weight which it will be capable of suspending will be the greater the more rapidly the zinc is dissolved.

The electric current which supplies the moving force is produced by the oxidation of the zinc. If we burn the zinc under the boiler of a steam-engine, we also oxidize it, producing thereby steam, and a certain amount of force. Now it has been proved by experiment, that 6 lbs. of zinc in combining with oxygen, develops no more heat than 1 lb. of coal; consequently, *under equal conditions*, we can produce six times the amount of force with 1 lb. of coal, as with a pound of zinc. It is therefore obvious, that it would be more advantageous to employ coal instead of zinc, even if the latter produced six times as much force in a galvanic battery as an equal weight of coal by its combustion under a boiler. Indeed it is highly probable, that if we burn under the boiler of a steam-engine the quantity of coal required for melting the zinc from its ores, we shall produce far more force than the whole of the zinc so obtained could originate in any form of apparatus whatever.

Machinery for the manufacture of paper was illustrated by a model of Fourdrinier's first machine, and a model of the modern machine by Donkin. The French exhibited a full-sized

machine, but no idea of its marvellous powers could be formed by visitors in its state of repose. Indeed, to have worked this and many other machines and engines effectively, would have required a small river to have been conducted through the building. Samples of wire cloth used in paper-making machines were exhibited.

Various *centrifugal machines* were exhibited for separating water from clothes, or molasses from sugar. The machine exhibited by Napier & Son had a continuous action, so that the sugar or other material could be charged and discharged without stopping the machine, thereby preventing the loss of power in getting up the speed again, which, where high speeds are used, is considerable.

Sugar-crushing mills, sugar-refining apparatus, rope-making machines, and innumerable highly ingenious contrivances must be passed over without notice in this place. The more important will be described or noticed in the Cyclopædia. We must, however, find a place for a description of an important piece of apparatus, invented by Colonel Morin, and used by the jury of Class V. (*Machines for direct use*) in examining and reporting upon several machines in which one and the same object was sought to be attained by various modifications and combinations of similar parts. It was in this case most important to determine how far the various modifications had tended to produce economy of operation; and the jury had recourse to actual experiment with the apparatus exhibited. It was therefore necessary to have some means by which the amount of power actually used, to produce with any machine a given quantity of useful effect, could be accurately measured; and the Dynamometer, which had its origin in a suggestion of General Poncelet, and was brought into its present perfect form by Colonel Morin, furnished at once a most perfect and yet simple means of ascertaining this expenditure of power. Several modifications of this instrument were exhibited by M. Clair, of Paris, and permission was readily obtained for the use of these in the jury investigations. In its simplest form, as applied to measure the mechanical force transmitted by an ordinary wheel or pulley, which intervenes between any source of power and the machine to be tested, the dynamometer has the form represented in Fig. LXXII. A is a stout axle of iron turning freely in its bearings, and carrying a pulley or drum C. This pulley is keyed to the axle, and turns with it. On the axle a second pulley D, of the same dimensions as C, is placed, but is not keyed on or otherwise connected to the axle, except by the intervention of the spring E. This spring has one end fastened to the axle, while the other end is held firm by two cheeks projecting from the side of the loose pulley D. Then it is obvious that if any resistance were acting on the pulley C, to prevent its rotation, and a force were applied to D, to overcome this resistance, this force could only operate upon the pulley C by the intervention of the spring E, which would be bent, until its resilient tendency became just equal to the resistance acting upon C. The pulley D, having no connexion with the axle but through the spring E, transmits any force only by the flexure of the spring; and consequently, if the resistance on C were continuous, such as would arise from C being made to drive any machine, as, for example, a lathe, pump, blowing-fan, &c., and the power used to set this machine in motion were applied to D, the spring would always maintain a flexure corresponding to the resistance operating on C. As this resistance varied from one moment to another, from the different circumstances of the operation of the piece of machinery, so would the flexure of the spring vary, to accommodate itself at all times to the working force actually passing through the dynamometer. If, therefore, any means were applied, by which the degree of bending of this spring could be at all times accurately recorded, we should have a complete indication of the varying power expended during any given time, in effecting any operation by the machine supposed to be under examination. In order to attain this object, the same boss which holds the heel of the spring E carries a framework *f f*, serving to support a series of rollers *g*, *h*, *i*, a fusee *j*, and a pencil-holder *k*. On the edge of the pulley D is another pencil-holder *l*. When the dynamometer is to be used, a long ribbon of paper is wound on the roller *h*, and its outer end, being carried over the roller *g*, is made fast to *i*. The roller *i* is driven by a string which passes from it over the fusee *j*, and this latter bears on its axis a wheel *m*, gearing into another wheel *n*, placed on the axis A. Then it is obvious that when, by the revolution of the dynamometer axis, the

wheel m is turned, the string will wind gradually upon the fusee j, and the paper will be drawn from the roller h over g, and coiled upon i. The introduction of the fusee and string ensures a perfectly uniform rate of motion of the paper, notwithstanding the continually increasing diameter of the cylinder i upon which it is winding. Finally, two spring pencils are adjusted in the holders k and l, until their points press lightly on the ribbon of paper, and are (so long as the spring E remains unbent) exactly opposite to one another, so as to trace only a single line as the paper is drawn under them. The wheels m and n have their teeth cut in sloping directions, so that one will drive the other when placed, as in the machine, in planes perpen-

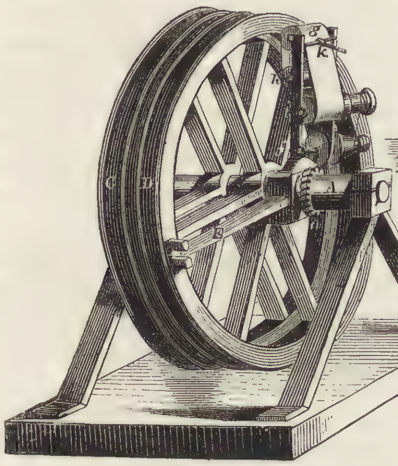


Fig. LXXII.

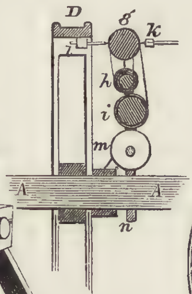


Fig. LXXIII.

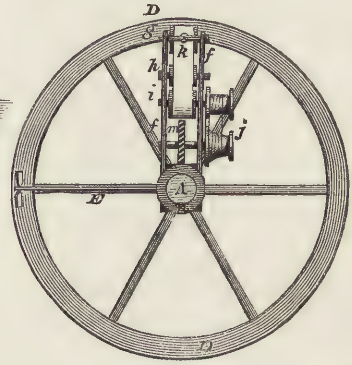


Fig. LXXIV.

MORIN'S DYNAMOMETER.

dicular to one another. When the dynamometer is now set in action, the spring E being more or less flexed, the pencil-point l is carried to the right or left of k; and consequently, as the paper is drawn under these points by the string winding upon the fusee j, the pencil k on the frame f continues to trace a straight line on the paper, while the other, l, fixed to the wheel, traces a curved line at distances from the straight line varying exactly as the flexure of the spring, and therefore exactly as the driving force transmitted by the dynamometer, varies. An arrangement is made by which the toothed wheel n can be either fixed or let free in an instant by the observer. It is evident that when rendered stationary, it will drive the other wheel m, which gears into it; but when let free, the two wheels are simply carried round together by the axis, without any relative motion. The observer, therefore, only allows the paper to move during a given period, which may be either that of a certain number of seconds, or of a given number of revolutions of the wheel; or, if a steam-engine be the original source of power, during a certain number of strokes of the engine. As soon as the experiment has been made, the machine is stopped, and the paper unwound. Now it is evident that the lengths of the lines traced, or the length of paper drawn under the pencil-points, bears a certain definite and predetermined ratio to the space through which the circumference of the pulleys C, D, has moved; that is to say, the space through which the driving force has acted; while the distance of the two lines asunder bears at every moment a definite proportion to the intensity of the force which has been passing through the machine. The first of these is the measure of the abscissa of the curve traced, while the ordinate of the curve drawn at any part represents the force acting at the corresponding moment of the experiment. Hence, the area of the curve gives the product of the amount of force acting continually, by the space through which it acts; that is, it gives the exact quantity of *work* which has been passed through the dynamometer into the machine to be tested. A corresponding observation having been made of the useful effect yielded during the same period, as, for example, the number of pounds of water raised to a given height, or the number of cubic feet of air delivered at a certain density by a fan, &c., an exact

measure is obtained of the ratio of these two results, and the *duty* of the machine under examination is determined with mathematical accuracy.

A second mode of registration which is sometimes employed deserves remark. In this the wheel *n* is made, instead of driving a fusee, to turn a small plane disc, covered with hard sole-leather. On this disc the edge of a small steel wheel presses lightly, and to the axis of this wheel a common registering train, like the register of a gas-meter, is attached. The leather disc is attached to the frame *ff*, the steel wheel to the pulley D. The position of the wheel is adjusted so that, when the spring is not flexed, the edge of the wheel shall press exactly on the centre of the disc. In this position it is evident that the disc, when driven by the wheel *n*, has no tendency to turn the steel wheel. But when the spring is flexed by the passage of power through the dynamometer, the steel wheel is moved away from the centre of the disc to a point nearer the circumference, and is therefore, in consequence of the friction between its edge and the surface of the disc, driven with a greater or less speed, depending on the relation between its own diameter and the diameter of that circle on the disc upon which its edge is at any moment pressing. Hence, the extent of rotation of the steel wheel is at once a measure of the product of the intensity of the acting force, by the space through which it acts; and this being registered during any given period, as before, gives one of the values required for the determination of the "duty" sought.

The degree of precision attainable with this apparatus is remarkably great. It is easily applied to any machine, and it furnishes at once, information most valuable both to the maker and the employer of machinery. It will be seen that many modifications of the form of the apparatus may be made, to suit the special circumstances of each case; and additional springs are easily fitted into the other sides of the boss, and connected with the pulley D, so as to render the machine capable of measuring forces of higher intensities.

The results which have been obtained with this dynamometer by the French engineers have been of the highest interest. The commercial value of various forms of machines in common use, such as pumps, blowing apparatus, and many manufacturing machines, have been ascertained and tabulated; and the surprising differences which are shown in the duties of the various modifications of each, prove at once the importance of introducing this apparatus more generally into our own country.

Section XV.—The Close of the Exhibition.—Retrospect.

The state of the metropolis throughout the whole period of the Great Exhibition will be remembered with wonder and admiration by all who visited it during that eventful season. Instead of the confusion, disorder, and demoralization, if not actual revolution, which were foretold by some gloomy minds, and instead of the famine and pestilence confidently predicted by others, as the inevitable consequence of assembling such vast multitudes in one city, London exhibited a wonderful degree of order, good-humoured accommodation of her crowds, and power to provide for their wants; while the general health of the metropolis was good, we believe, beyond the usual average, and the disorders in conduct were wonderfully few and trifling. It was not even necessary for any special steps to be taken on the part of the authorities for the housing of the guests. From all nations, and from every part of our own thickly peopled land, indeed, they came; but such were the hospitalities exercised, the contrivances made, and the extensive arrangements due to private enterprise, that these, taken in conjunction with the shortness of the visits, and the rapid succession of the guests, enabled our city to comprehend within her wide limits a large assemblage of visitors, in addition to her own formidable number of two millions and a half. The order and precision with which carriages and foot-passengers were marshalled in the great thoroughfares, and occasions of tumult prevented and removed, reflected the highest credit on the metropolitan police, who, unaided by soldiery, and simply by the increase and discipline of their own numbers, and by the general good feeling of the populace and the visitors, sufficed to keep the peace of the vast city. Thus, enormous excursion-trains daily poured in their thousands or their tens of thousands, without disturbing the equanimity of the settled residents; or, if some fled in alarm, they soon found how ill-grounded

and unnecessary were their fears. There were numbers, no doubt, who, like ourselves, felt the time of the Great Exhibition one of unusual and affecting interest. Friends came across the seas, or from remote parts of our own land; kinsfolk, long estranged, perhaps, on that occasion met; whole families collected in happy groups, and cared not much for the nature of their accommodation, so that they *might* but collect, and enjoy together the wondrous spectacle :—there were, indeed, meetings and partings to mark the year for ever in memory's page. Throughout the season there was more of unrestrained and genuine fellowship, and less of formality and customary ceremonial, than has, perhaps, ever been known in English society. It was like assembling for a gigantic picnic, where each feels privileged to roam at will, and all are disposed to yield something to the exigencies of the occasion. It was truly a picnic to numbers of visitors at the Great Exhibition; for country parties took leave to carry with them large baskets of provisions, and sat in the open-air courts to partake of them. Among the excursionists were large numbers of workpeople, who, through the generosity of their employers, received holidays for the purpose, and in many cases, also, the means of defraying their expenses on the visit. Thus a party of 800 agricultural labourers, in their peasants' attire, and decorated with rosettes of coloured ribbons, assembled from a district in Surrey and Sussex, and came to London by special train, conducted by their clergy. They walked in procession to Hyde Park, where, after feasting their eyes sufficiently with the wonders of the Crystal Palace, they returned to their own villages, having gained this pleasure at the small cost, in travelling expenses, of two shillings and twopence each person. Numerous large firms in the North sent the people on their establishments, many of whom must have been gratified by the sight of their own handywork among the great and gorgeous things that met their eyes. Indeed, one of the distinguishing features of the collection in Hyde Park was the *universality* of its attractions. The humblest workman had there his own peculiar objects of interest, as well as the most accomplished mechanician. A carpenter's apprentice would be as much delighted and surprised at the collection of tools belonging to his trade, and the several varieties introduced among different nations, as the mathematical instrument maker would be gratified by the opportunity of comparing his own highly-finished productions with those of foreign countries.

Among the workpeople-excursionists the arrangements were in some cases very complete. Thus, an eminent agricultural implement maker in Suffolk sent all his people in two hired vessels, provided with sleeping-berths, cooking-apparatus, and every comfort. These vessels, drawn up to a wharf at Westminster, furnished homes to the excursionists during their stay in London. The precise time for meals and for return to the vessels at night was laid down, and a foreman was there to enforce the observance of the rules. In this safe and economical manner a large number of persons were privileged to view, not only the Great Exhibition, but many other attractive sights of London. Several admirable plans were arranged by gentlemen of fortune for affording their dependents an opportunity of sharing in the festival of the year: one in particular, organized by the Duke of Northumberland, and conducted at his expense, provided, by printed directions, for the employments of each day and hour, so that the 150 persons who availed themselves of this guidance were able to see most of the principal objects of attraction in the metropolis within one week. Thus, private individuals, manufacturers, friendly societies, clergy, and all others possessing extensive influence, seemed to vie with each other in affording to their neighbours and workmen the gratification which on their own part was so highly appreciated. It was also largely extended to children. Nearly 44,000 school-children visited the Exhibition, of whom 2,700 were in the building on one day (Sept. 18).

This systematic and general sanction of the undertaking by employers, with the gradually increasing number of general visitors, could not but affect the railways in a remarkable degree. Trains containing one thousand persons were common; but trains of two and three thousand were also known, and one immense train from Bristol brought five thousand persons. To those living in the neighbourhood of the various termini, it was curious and interesting, though not always pleasant, to watch the arrival and pouring forth of the densely packed masses of persons by these gigantic trains, and to hear the almost uninterrupted groanings, hissings, and screams of the heavily-taxed engines. The total receipts of the

railways having termini in London are said to have been 800,000*l.* greater during the Exhibition than during the corresponding period of the previous year.

To meet the wants of this array of visitors, a great number of Guides, Handbooks, &c. to the Great Exhibition were brought out, and met with remarkable success. Everything relating to the Crystal Palace sold well, but above all the Official Shilling Catalogue. Persons who are fond of making curious calculations have assured us that if the whole of the earlier editions of this catalogue had been consigned in one vertical column to the Pacific Ocean, the depth of which is estimated at 6,000 feet, the last edition would still have formed a lonely peak, rising to the height of Chimborazo or Cotopaxi, 18,000 feet above the level or the censure of the ordinary inhabitants of this earth. Another abstruse calculator discovered that if the whole of the catalogues sold had been raised into a vertical pile, it would have exceeded the height of St. Paul's Cathedral fifty times! however impossible it may appear to a Londoner that any terrestrial object should exceed that noble pile in height. It was further discovered that the number of catalogues sold was equal to about one-fifth of the estimated number of printed volumes issued from the printing-press within the first three centuries after the discovery of the art of printing. We fear, however, that the reader will not be able to gather from all this how many copies of the catalogues were really sold. The number was upwards of 300,000; and the printer informs us that the paper required for this number weighed 118 tons, and the type 70,000 lbs. Another curious statistical fact connected with the Great Exhibition is, that the total number of letters on the subject received by the Executive Committee amounted to 37,000.

During the twenty-four weeks of the Exhibition, more than six millions of persons visited the building, the numbers rising immensely towards the close, after some previous fluctuation. The opening month did not bring the amount of provincial and foreign visitors expected, but at the end of May, when the price of admittance was lowered, the attendance was greatly increased. The visitors were registered in two classes, those who were ticket holders, and those who paid money at the doors, answering to subscribers and non-subscribers. Of the former, the daily attendance during May averaged upwards of 14,000, while the latter also assembled in large numbers, as will be seen by the following table:—

	Total Number	Daily Average.		Total Number.	Daily Average.
Week ending May 10	118,253	19,709	Week ending Aug. 2	288,519	48,086
... 17	145,507	24,251	... 9	286,771	47,795
... 24	192,869	32,145	... 16	252,057	42,009
... 31	222,114	37.019	... 23	236,539	39,423
June 7	247,928	40,988	... 30	211,447	35,241
... 14	238,585	39,764	Sept. 6	214,623	35,770
... 21	303,015	50,502	... 13	254,032	42,339
... 28	292,709	48,785	... 20	273,330	45,555
July 5	246,739	41,123	... 27	275,367	45,894
... 12	288,427	48,071	Oct. 4	322,848	53,808
... 19	305,853	50,976	... 11	518,277	86,379
... 26	274,139	45,690			
Total 6,009,948.		43,311 Mean Daily Average.			

In addition to these numbers, we must also take account of the opening day, when the holders of season tickets only were admitted, and the two following days, when the admission fee was 1*l.* There were also two exhibitors' days, and the closing day. In these six extra days, there were about 160,000 visitors not included in the above estimate, so that the total number of visitors, was, in round numbers, 6,170,000, or nearly 43,000 per day for 144 days. A large deduction must however be made from this and all other calculations, in which it is assumed that upwards of six million persons visited the exhibition. The editor visited the exhibition upwards of fifty times, so that he alone would count for more than fifty persons out of the six millions; and as many other persons visited the building many times, it is impossible to calculate what was the actual number of visitors. If the average be taken at two visits per head, that would make the number of visitors upwards of three millions.

It will be seen by the above table, that from the opening until the middle of June, the numbers steadily rose, and continued high for nearly two months, when there was some abatement. But as the closing period approached, the concourse became such as no previous occasion had witnessed, so that the last four shilling days presented the following extraordinary results :—

Attendance on	Monday	Oct.	6th	107,815
	Tuesday	„	7th	109,915
	Wednesday	„	8th	109,760
	Thursday	„	9th	90,813

The Friday and Saturday of that week also presented very high numbers, when it is considered that both were half-crown days. On Friday it was 46,913, and on Saturday (the public closing day) 53,061.

The amount of provisions consumed at the several refreshment stalls within the Exhibition was something enormous, being in round numbers about as follows :—

Bread	52,000 quarterns.	Ham	70,000 lbs.
Small loaves, rolls and biscuits	120,000	Beef, tongue, &c.	260,000 lbs.
Plain buns	870,000	Rough ice	800,000 lbs.
Bath buns	930,000	Salt	80,000 lbs.
Banbury and other cakes	220,000	Milk and cream	65,000 quarts.
Cake sold per lb.	50,000 lbs.	Tea, coffee, and chocolate	21,000 lbs.
Meat patties and rolls	80,000	Lemonade, soda-water, and ginger-beer	1,090,000 bottles.

The arrangements made by the Executive Committee for the convenience and security of visitors, were in every respect admirable. Indeed, the care was similar to that bestowed upon a large city, for the Exhibition had its own post-office, electric telegraph, and branch bank; its little army and police; its cafés and table-d'hotes, with other arrangements for decency and health. There were upwards of 900 persons officially employed, including 200 sappers and 400 police. Exclusive of those, there were 264 attendants at the refreshment stalls and rooms, and about 1,000 exhibitors' attendants. By the wise regulations adopted, the building was kept (with few exceptions,) from extremes of temperature. The temperature was not too high before the 19th of June, when there was a sudden rise in temperature of 10°, the 18th showing 64·8°, and the 19th 74·8°. This was a shilling day, with 63,836 visitors. It was then clear that if this weather continued, something must be done beyond the extensive ventilating apparatus already in use; and it did continue, so that on the 26th the thermometer rose 2° above summer heat,—namely, 78·6°. On that day the temperature was the highest felt during the Exhibition. At 4 P.M., the thermometer, No. 5, placed on the north-east corner of the gallery among the wax flowers, registered 97°, and the air was insufferably hot and oppressive. After serious consultation, it was decided that the glass ends of the building, at the entrance, should be removed. This was done on the 2d of July, on which the thermometer came down from 79·4° to 66·6°. After that 73·4° was about the maximum.

The associations and emotions connected with the close of the Great Exhibition, were not less worthy of note than those of its opening, although no gorgeous pageant celebrated the occasion, and no royal presence graced the scene. The writer was present during the whole of that eventful week, spending the greater part of each day in a general review of the whole building, and its apparently exhaustless treasures; for numerous objects of instruction and interest came to light, which had escaped the diligent study of the previous months. But a review of this kind was performed under considerable disadvantages, where the visitors themselves, swelling into vast importance, became, in fact, a most impressive part of the Exhibition. To look upon that immense multitude from the gallery over the eastern entrance, (where the effect was ever the most picturesque,) was a thing never to be forgotten. No trace of the broad extent of flooring in the nave was visible, but over its surface waved a mass of living forms, like billows on the deep. As in the world of waters, the foremost waves, rich in their manifold tints and shadows, have the grandest and most imposing appearance, while further off, perhaps, a parting cloud allows a sparkling band of waves to dance in the sun's rays, and dazzle the eyes with their brilliancy; and yet further, the tender hue of the waters blends with that of the horizon: so, also in this living ocean, there were rich and varied colours, deep shadows, constant agitation, eddies, and currents in the mass nearest the eye; and these effects, softened and

lessened by distance, were yet perceptible, until a broad band of light revealed the transept, where, unchecked, the sunbeams fell on sparkling fountains, trees, and flowers, and where the living waves glittered in their constant rise and fall. Further still, the eye could dimly trace the same incessant motion in the western nave, and here the softened and subdued colours, blending with the *visible* atmosphere in the extreme distance, gave the billowy effect in great perfection. There was a charm about that sight, similar to that with which we are enchained to one spot in viewing the ocean, and there was also a peculiar effect on the ear, like the wind sweeping over a forest, or the gushing sound of streams. This arose from the footsteps of the vast multitude, blended with the noise of distant machinery in motion, and the falling of water from the nearer fountains. This monotonous and soothing sound was often lost in the pealing forth of mighty organs, or in the trumpet tones with which stragglers were summoned to make their way through the throng, and rejoin their friends at some appointed place of meeting. But there were occasions when the musical performances were altogether suspended, that no undue pressure in any one spot might endanger the safety of the multitude. As the closing week wore on, a gloom came over the weather, (which throughout the season had been almost constantly fine,) and over the looks of the visitors. The restless movements of the latter reminded one of the agitation of a swarm of bees about to migrate : they seemed unable any longer to dwell with admiration on particular objects, but wandered from place to place with regretful looks, taking a general farewell. This was especially remarkable on Saturday, the 11th of October, the public closing day. On this, and the previous week, the usual Saturday price of *5s.* was lowered to half-a-crown, and the numbers on the closing day were higher than on any former half-crown day. From a general expectation also that some closing ceremony would take place, the numbers present did not disperse to the same extent as usual over the subordinate parts of the building, but closely thronged and promenaded the nave, transept, and front galleries. The strains poured forth by the several organs on this occasion, were all of a sacred or solemn character, and calculated to awaken emotions of thankfulness and praise. There was much excitement as the hour drew on, when the striking of the clock should announce the closing scene. People rushed wildly up the staircases, in the hope of getting a better view above than below, but soon came back on finding the crowded state of the galleries near the transept, which was the great point of attraction. The corners of these galleries had been appropriated to choral societies, who, in default of any formal ceremonial, had agreed to unite with the great mass of the people, and with all the organs in the building, in raising the grand national anthem. The first signal of the close was the stopping of all the fountains. There was a sort of breathless attention for a few seconds preceding the striking of the hour of five, when the Great Exhibition virtually closed to the public. Then came the peal of organs, and the mighty chorus of fifty thousand voices, followed by a still mightier cheer, which ran through the building as the parting acclamation of a gratified people. This was further enhanced by the stamping of the feet, which caused a deep rolling sound resembling thunder, and by the waving of hats and handkerchiefs; producing continued lines of motion through the vast space. Altogether, such a cheer and such excitement have been seldom witnessed. And when all this was over, and the loud bells and gongs warned the crowd to leave the building, they neglected the discordant summons. Long and lingeringly did they hang about the favourite spot, and with much forbearance did the authorities suffer this touching display of fondness, allowing many to remain till artificial light became needful. Numbers of female visitors looked back with tearful eyes, as they were led reluctantly from the scene of many months' intellectual pleasure and instruction. Few persons of true feeling could be wholly unmoved in saying farewell to the Crystal Palace.

To many present, however, this was not the final parting; for the exhibitors, each accompanied by two friends, the members of the Society of Arts, and a few other privileged persons, were allowed to enter the building on Monday and Tuesday of the following week, while preparations were making for the simple and comparatively private ceremony of Wednesday, when *only* exhibitors and members of the above Society were present, and when the Prince Albert closed the Exhibition. On Monday and Tuesday, the first of those who came in their capacities of exhibitors were the Queen and the Prince. And here

we may appropriately speak of the zealous and indefatigable interest in the Exhibition displayed by these illustrious persons. In the early morning hours, when many of her subjects were profoundly sleeping, Queen Victoria paid almost daily visits to the Crystal Palace, and explored its treasures with a systematic attention, which few other ladies appeared willing to bestow. Not contented with the examination of rich gems, magnificent lace and embroidery, splendid furniture, elegant carriages, and such like attractive objects, our gracious Queen explored the several departments with an evident determination to make herself acquainted with every branch of manufacture therein illustrated, however humble it might be. Listening patiently to descriptions of complicated machinery and processes, and viewing their extraordinary and often magnificent results, we may presume to infer that many new sources of instructive interest were opened to the royal mind, and that during these repeated and prolonged visits to the Crystal Palace, opportunities were presented to our Sovereign of studying the several descriptions of human labour and ingenuity, such as, from the very circumstances of her position, she could never before have enjoyed. With the Queen came the Prince, and sometimes the royal children. The appearance of the group ever created the liveliest interest, and many were the happy country visitors who went back overjoyed at the unexpected pleasure of having seen Queen Victoria walking unostentatiously through the noble aisles of the Crystal Palace. Scarcely inferior to the excitement produced by the presence of the Queen and Prince, was that manifested on the appearance of the Duke of Wellington. A cry of "The Duke, the Duke!" and a rush to the front of the gallery to look down on the veteran figure, first called our attention to the appearance of this illustrious man. Visitors drew back as from a royal presence, leaving a line open for his movements, behind which the throng eagerly collected. The brief military salutation, and the sudden retreat into a side court, showed the Duke's appreciation of this homage and desire to escape from it. But to return:—On these exhibitors' days, the sound of workmen's hammers constantly reminded one that the work of demolition had begun. Several of the more valuable objects were removed, especially those in and near the transept, to make room for the platform on which the official bodies were to meet on Wednesday. On Tuesday morning, the crystal fountain had disappeared, the Koh-i-noor was gone, and we arrived at the spot just as two of the sappers and miners were carrying off the Prince of Wales's silver shield. The treasures of the Indian collection had also been rifled, and empty benches with their torn coverings of crimson cloth alone remained at those corners of the transept which had shone the most brilliantly in gems and embroidery. Still the attendance of visitors (the privileged class above-named) was very large, and still from the transept gallery poured forth the notes of that splendid wind-instrument, the Sommerophone, with which its inventor, Herr Sommer, had for many weeks delighted the visitors. The sounds of his "Farewell to the Exhibition" were the last we heard on Tuesday evening.

The ceremonial of Wednesday, 15th of October, took place amidst drenching rain. George Herbert's words, slightly varied, were applicable,—

> "The *rain* shall weep thy fall to-night,
> For thou must die."

The chief object of the meeting had respect to the important subject of the prizes to be awarded to those who had attained certain prescribed standards of excellence. It was attended by His Royal Highness Prince Albert, the Bishop of London, the Royal Commissioners, the Jurors, the Exhibitors, and all other persons officially connected with the Great Exhibition. Lord Canning, as the chairman of the Council of Jurors, submitted to His Royal Highness the reports and awards, and explained, in an address of considerable length, the grounds upon which the Council had acted in giving effect to the decisions of the Commissioners. The Juries were thirty-four in number, and each consisted of an equal number of British subjects and foreigners. In the event of any jury finding themselves deficient in technical knowledge of an article submitted to them, they were empowered to call in the aid of associates, who acted as advisers only, without a vote, but whose services were of the greatest value. Each jury possessed its own chairman, deputy chairman, and reporter; but no jury acted independently of the rest, for they were associated in groups, as the subjects

relatively assigned to them bore relationship to each other. Each group of juries also received the assistance of a deputy commissioner, and of a special commissioner, for the purpose of recording its proceedings, and furnishing information respecting the Exhibition, which might facilitate its labours. The chairmen of the several juries formed the council, whose duties were to determine the conditions upon which the different prizes should be awarded, so as to accord with principles previously laid down by the Commissioners, to frame rules for the guidance of the juries, and to secure, as far as possible, uniformity in the result of their proceedings.

Two medals were awarded, (three had been decided on at first,) one, the prize medal, being given wherever a certain standard of excellence in production and workmanship had been attained,—utility, beauty, cheapness, adaptation to particular markets, and other elements of merit being taken into consideration according to the nature of the object; the other, and larger medal, being conferred for some important novelty of invention or application, either in material or processes of manufacture, or originality combined with great beauty of design, and not simply for excellence of production or workmanship, however eminent. The former medal was awarded by the juries, the latter by the council of chairmen, upon recommendation of a jury, supported by its group. The number of prize medals awarded was 2,918; the number of council medals 170. The total number, including a very extensive list of "Honourable Mentions," was 5,084: of this gross number, 3,045 distinctions were granted to foreign exhibitors, and 2,039 were received by our own countrymen. The number of exhibitors was about 17,000.

In reply to Lord Canning's report, His Royal Highness Prince Albert noticed in terms of high approbation the zeal and ability of the distinguished gentlemen of this and other nations who had acted on the juries, while he also adverted to the peculiar difficulties which they had had to encounter. In connexion with the award of council medals, His Royal Highness remarked, "Important discoveries in many branches of science and of manufactures have in this Exhibition been brought under the notice of the public; and it seems just, that those who have rendered services of this kind to the world, should receive a special mark of acknowledgment on an occasion which has rendered so conspicuous the advantages which the many have derived from the discoveries of the few." The Prince also justified the bestowal of the council medal for beauty of design, and for excellence in the fine arts as applied to manufactures, as being "a testimony to the genius which can clothe the articles required for the use of daily life with beauty that can please the eye, and instruct and elevate the mind;" and added, "Valuable as this Exhibition has proved in many respects, it appears to the Commissioners that there is no direction in which its effects will be more sensibly and immediately perceived, than in the improvement which it may be expected to produce in taste, and the impulse it has given to the arts of design; and a special acknowledgment is justly due to those who have afforded the best examples of art, whether pure or applied, and led the way in this interesting career of improvement.

After tendering cordial thanks in the name of the Royal Commissioners to all who had cooperated with them in this great undertaking, His Royal Highness concluded in the following words:—

In now taking leave of all those who have so materially aided us in their respective characters of Jurors and Associates, Foreign and Local Commissioners, Members and Secretaries of Local and Sectional Committees, Members of the Society of Arts, and Exhibitors, I cannot refrain from remarking, with heartfelt pleasure, the singular harmony which has prevailed amongst the eminent men representing so many national interests,—a harmony which cannot end with the event which produced it. Let us receive it as an auspicious omen for the future; and while we return our humble and hearty thanks to Almighty God for the blessing which he has vouchsafed to our labours, let us all earnestly pray that Divine Providence, which has so benignantly watched over and shielded this illustration of Nature's productions, conceived by human intellect, and fashioned by human skill, may still protect us, and may grant that this interchange of knowledge, resulting from the meeting of enlightened people in friendly rivalry, may be dispersed far and wide over distant lands; and thus, by showing our mutual dependence upon each other, be a happy means of promoting unity among nations, and peace and good-will among the various races of mankind.

On the conclusion of this address, the Bishop of London offered up an appropriate prayer, and the whole proceedings were closed by the singing of the Hallelujah Chorus.

CYCLOPÆDIA OF USEFUL ARTS,

Mechanical and Chemical,

MANUFACTURES, MINING AND ENGINEERING.

ABATTOIR (from the French verb *abattre*, to fell or knock down), a term applied to an establishment situated on the outskirts of a large town, where animals are slaughtered for supplying the inhabitants with meat. In ancient Rome, a corporation of butchers had the privilege of supplying the city with meat. These butchers, who were for a long period scattered over different parts of the city, were at length collected into a single quarter. In the reign of the Emperor Nero, the grand market, with its slaughter-houses, formed a magnificent establishment, which has been recorded to posterity in a medal. In Paris, from time immemorial, a corporation of butchers had the privilege of purchasing cattle and supplying the city with meat; but here the policy of the Romans ceased to be imitated, for the cattle, purchased at the markets of Sceaux or Poissy, were driven through the public streets to the butchers' shops, before which they were slaughtered and prepared for sale, the refuse animal matters being stored in large tubs; the whole arrangement being as dangerous to the persons and health of the inhabitants as it was offensive to the sight. Many of the objections which applied to Paris, still apply to London and other large towns of England.

A remedy for these evils had long engaged the attention of the French government. The butchers themselves were most energetic in opposing a change; but at length the strong hand of the Emperor Napoleon put down all opposition, and, by a decree dated 9th February, 1810, it was ordered, that five abattoirs should be erected in the neighbourhood of Paris at the expense of the city, under the direction of a Committee of Architects and Engineers appointed for the purpose. Plans were accordingly prepared with the assistance and advice of a retired master butcher. Eight years were occupied in carrying them into execution, and they were opened for public use in 1818.

The five abattoirs of Paris are those of Roule, and

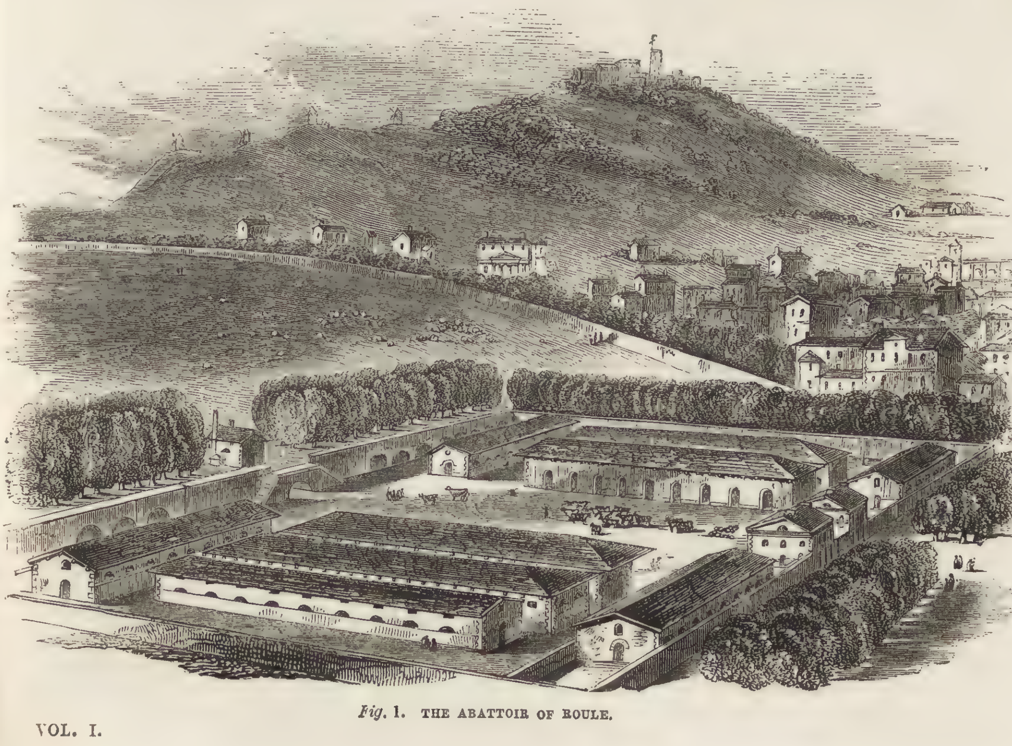


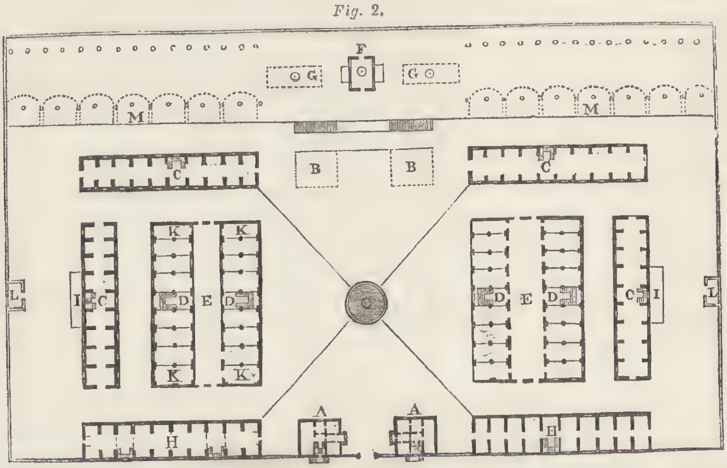
Fig. 1. THE ABATTOIR OF ROULE.

Villejuif, each provided with thirty-two slaughter-houses; Grenelle containing forty-eight, and Ménilmontant and Montmartre, each containing sixty-four slaughter-houses, making altogether 240 slaughter-houses. This is less than the number of butchers in Paris; but as some butchers contract with others for having their cattle slaughtered and prepared for sale, and as in some cases one slaughter-house is shared by two or three butchers, whose respective trades are but small, the number of slaughter-houses has hitherto been found sufficient. When the meat has been properly prepared for sale at the abattoirs, it is removed in carts to the various markets and butchers' shops of the city.

By these arrangements, not only is the city freed from a disgusting and even dangerous occupation, but additional facilities are afforded for inspection. As all the cattle slaughtered for the supply of Paris must be driven into the abattoirs, the inspectors can easily ascertain whether the animals are healthy, and in a fit state to furnish food to human beings. Besides this, all the offal and refuse animal matters can be easily collected together, for supplying various trades which are dependent on the slaughter-houses, such as the manufacturers of glue, of gelatine, of Prussian blue, of hoof-oil, of blood-manure, &c., whose works are collected near the abattoirs, and thus relieve the city of trades which are as offensive, or even more so than the occupation of the slaughterer.

A very favourable idea of these establishments will be conveyed by the accompanying view of the abattoir of Roule. (Fig. 1.) As the original site of this abattoir was on sloping ground, the earth excavated during the process of levelling was formed into an esplanade before the entrance. Plantations were here formed, and a beautiful avenue of trees thus separates this abattoir from surrounding buildings. At the upper part of the slope the earth is supported by arches, the vaults of which serve as coach-houses and stables, and above is a spacious terrace also planted with trees. Fig. 2 is a ground plan of this abattoir, which may be taken as the

Fig. 2.



type of all the rest. At the entrance are two small buildings A A, the residences of the inspectors, superintendents, porters, &c. When the animals first arrive at the abattoir, they are driven into the open spaces B B, where they remain until the butchers arrive and take them to the lay-stalls C C. These edifices have about thirty feet of internal width. On one side the oxen are arranged, and on the other side the sheep and calves. There are racks and bins for fodder, and a large water-trough. The upper stories of these buildings are divided into small rooms, which are used as granaries, one of which is appropriated to each butcher. D D are ranges of slaughter-houses separated from each other by a court-yard. Each slaughter-house is about $16\frac{1}{2}$ feet wide by $32\frac{3}{4}$ feet long, and is furnished with two entrances, one by which the animals are introduced, and the other, on the external front, for removing the carcases. There is also a cock for supplying the water required in washing, a channel sunk below the paved floor, a windlass and a pulley for drawing up the carcass to be flayed, and a couple of poles fixed into the wall at one end, seven feet from the ground, and supported at the other end by a stirrup iron, for hanging up the carcases of the oxen until they are ready to be removed. Pegs and hooks are fixed to the roof and walls for hanging up the carcases of calves, sheep and lambs. The following section and ground plan (Figs. 4 and 5) will further explain all these arrangements. The floors are paved with stone, and the joints well cemented. Small openings in the lower part of the door admit

Fig. 3. LAY-STALLS AND GRANARIES.

the air, and a large space is also left open below the roof, so that the air may circulate freely. The roof projects about 10 feet beyond the external walls, (see Fig. 6) for the purpose of sheltering the interior from the sun, and also to afford a cover for the carts which are sent to convey away the meat. This arrangement of the roof and door keeps the interior of each slaughter-house some degrees cooler than the external air, which is found to be far more effectual in preserving the meat from blow-flies in summer, than by enclosing it in canvass, perforated zinc, or other similar contrivances.

Fig. 4.

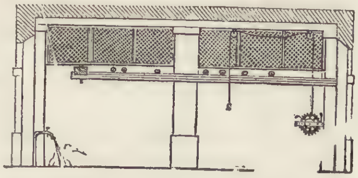


Fig. 5.

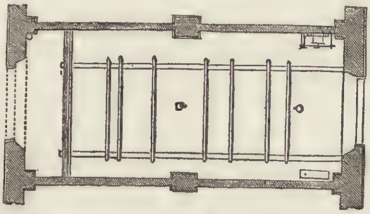


Fig. 6. SLAUGHTER-HOUSES.

An abundant supply of water is required for every part of the abattoir. This is furnished by a well, and is pumped up by a steam-engine F, into reservoirs G G. (Fig. 2.)

As the number of oxen taken into the five abattoirs of Paris is at least 75,000 per annum, the quantity of water required per day is, from about 8,400 to 10,500 cubic feet. But as the consumption is by no means uniform, it being very great on certain days of the week, and ceasing almost entirely on other days, it is necessary to keep up a supply in the reservoirs. Each abattoir is furnished with two, the larger of which is of the capacity of 6,300 cubic feet, and they are placed at such an elevation, that all the pipes distributed over the abattoirs are constantly supplied.

The superfluous fat and fatty parts of the animals which cannot be used as food, are melted down for the purposes of the tallow-chandler, soap-maker, &c. This is done in the melting-houses, H, which contain coppers of the capacity of from ten cwt. to forty cwt. of tallow. Under the same roof are places where tripe is prepared for sale.

The offal and refuse animal matters are collected from the various lay-stalls, slaughter-houses, &c. every day into the yard or shed I, (Fig. 2,) which is paved, and the joints between the stones made tight with cement. This court is cleared out and well washed if possible every day, to prevent any ill odour. The other letters of reference in Fig. 2. are K warehouses, L lieux d'aisance, M vaults under the terrace, N coach-houses and stables.

In addition to these arrangements, each abattoir is furnished with a capacious sewer, not shown in the plan, for receiving the various liquid animal matters from the lay-stalls, slaughter-houses, &c. This sewer is formed of hard gritty sandstone, and is three feet wide, and six feet high. The drains which lead into it from the various sections of the abattoir, are furnished at their upper part with a grating, sunk a little below the pavement, fitting into a short wide tube of which the lower extremity dips into a basin, and thus acts as a valve or stink-trap, (Fig. 7,) and effectually prevents gas from the sewer from rising up into any part of the abattoir. It will be seen from the diagram that the liquid matters which pass through the grating, fall into the basin and then overflow into the drain.

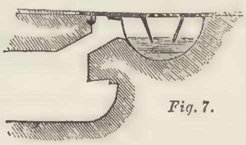


Fig. 7.

The revenues of the abattoirs are considerable. The butchers are charged six francs per head for all the oxen slaughtered; which, on 75,000 or 80,000 oxen, produces an annual revenue of nearly 500,000 francs. After paying all expenses, a considerable revenue goes to the municipal purse. The new system is also far more economical to the butchers themselves than the old method. It has been found also that by withdrawing the slaughterers from the public gaze, and insisting upon habits of neatness and order, the manners of this class of men have been greatly improved.

Abattoirs have been erected in the neighbourhood of all the large towns of France, and we hope the time is not distant, when London and the principal towns of Great Britain will be similarly provided.

ABUTMENT—See Bridge.

ACETIC ACID (from the Latin *acetum*, vinegar) is important in a manufacturing point of view, from its being the sour principle of vinegar. This acid occurs ready formed in some plants, and is produced during the spontaneous fermentation of many vegetable and animal juices. All liquids containing alcohol are capable of passing into the state of vinegar; and hence the manufacturer finds it convenient to employ those liquors in which the vinous fermentation is complete,—such as wine, beer, &c. When these liquids are exposed to the atmosphere, at a certain temperature, a new chemical change is induced, whereby oxygen is absorbed, and the alcohol gradually passes into acetic acid. This acid, as it exists in combina-

tion with certain bases, is composed of 4 atoms of carbon, 3 atoms of hydrogen, and 3 of oxygen; but in this state, which is called *anhydrous*, or without water, it has never been obtained separately. In combination with one atom of water, it forms what is called *glacial* acetic acid, from the circumstance of its freezing at a temperature of about 45°. This acid may be represented by the formula, $C_4\,H_3\,O_3 + HO$; that is, 4 atoms of carbon, 3 atoms of hydrogen, 3 atoms of oxygen, plus 1 atom of water. Now, as alcohol is composed of $C_4\,H_6\,O_2$, its conversion into anhydrous acetic acid will be seen to consist in the abstraction of two atoms of hydrogen, and the addition of two atoms of oxygen. Or, if we take 100 parts of alcohol, and 100 parts of hydrated acetic acid, we get—

52.6 carbon.	40.6 carbon.
12.9 hydrogen.	6.6 hydrogen.
34.5 oxygen.	52.8 oxygen.
100.0 parts of alcohol.	100.0 {parts of hydrated acetic acid.

Hence it will be seen, that acetic acid contains the same elements as alcohol, but in different proportions; there being less carbon and hydrogen, but more oxygen. It was formerly supposed that this change was brought about by the alcohol being deprived of a portion of its carbon and hydrogen, while the oxygen remained the same. More recent inquiries have proved that no carbonic acid is formed during the process; but that a portion of the oxygen of the atmosphere combines with a portion of the hydrogen of the alcohol to form water. The alcohol, thus partially deprived of its hydrogen, forms a new compound, named *aldehyde*, which contains the same proportions of carbon and hydrogen as acetic acid, but less oxygen; the deficient quantity of oxygen being afterwards supplied by the atmosphere.

The conversion of alcohol into acetic acid may be shown by a beautiful experiment,—the basis of a manufacturing process adopted in Germany. When vapour of alcohol is brought into contact with a black powder obtained by mixing muriate of platinum, potash, and alcohol, vinegar is rapidly formed; the powder absorbing and condensing the oxygen of the atmosphere, so as to enable the alcoholic vapour to combine with it. The arrangement is as follows:—Under a large glass case a number of earthen dishes, containing dilute alcohol, are arranged on shelves, one above another, and over each dish is suspended a portion of the moist platinum powder. A temperature of from 68° to 86° Fahr. is maintained, and the evaporation of the fluid is promoted by hanging several strips of porous paper in the case with their lower edges dipping into the dishes, whereby a greatly increased amount of evaporating surface is obtained. In a few minutes the mutual action of the platinum powder and the alcohol will cause an increase of temperature, accompanied by the formation of acid vapours, which condense on the sides of the case, and trickle down to the bottom. This action continues until all the oxygen in the air of the case is consumed; but the action is renewed by a fresh supply of air. If the case contain 1,000 cubic inches of air, this will suffice to oxidize 110 grains of absolute alcohol, and will produce 122 grains of anhydrous acetic acid, and 64½ grains of water. The platinum powder does not waste, and may, therefore, be used over and over again.[1]

In the general process of vinegar-making, some cheap ferment is usually made to take the place of the platinum powder in the above experiment. There are many substances containing nitrogen which answer this purpose, such as gluten, mucus, vinegar itself, or substances containing it, such as yeast, sour dough, sour beer, but especially sour bread soaked in vinegar. These substances, being in a state of inodorous putrefaction, decay, or oxidation, draw the alcohol into the circle of their decomposition, just as decaying wood causes fresh wood around it to assume the same condition. When the alcoholic liquor, mixed with the ferment, is exposed at a proper temperature to the atmosphere, the ferment is supposed to absorb oxygen from the air, and to transfer it to the alcohol. The liquor soon becomes turbid; slimy particles form in it, and collect as a scum on the surface; this scum thickens, and, after a time, falls to the bottom. The Germans call it the *vinegar mother*, and use it for the purpose of exciting acetification in fresh liquor. The temperature of the mass rises, and diffuses a peculiar aroma over the place. When all the alcohol has been converted into acetic acid, the action ceases, the temperature declines to that of the surrounding air, the liquor becomes bright, and may be drawn off as vinegar fit for the market.

All substances, then, that can be made to undergo acetous fermentation, either because they contain sugar, or that sugar is formed in them from starch, can be employed in the manufacture of vinegar;—as, for example, in malt, the starch is converted into sugar by the process of mashing, and the sugar is converted into alcohol by vinous fermentation.—[See Fermentation.]

According to the substance employed, the variety of vinegar receives its name in commerce, as—1. *Wine vinegar*, which is prepared from wine, and contains acetic acid, tartaric acid, and a minute portion of acetic ether, to which the pleasant aroma of this kind of vinegar is due. 2. *Artificial Wine vinegar*, or *Alcohol vinegar*. This is prepared from spirits, and consists almost entirely of acetic acid, water and a small portion of acetic ether. 3. *Fruit vinegar*, or *Cider vinegar*, from the fermented juice of apples; this vinegar contains, besides acetic acid, malic acid, which is a source of acidity in apples and many other fruits. 4. *Beer*, *Malt* or *Corn vinegar*, formed from the extract of malt, and contains, in addition to acetic acid, nearly all the constituents of beer, such as the phosphates of lime and magnesia, gum and an extractive substance which imparts colour, and causes the vinegar to froth on being shaken. There is a fifth variety of vinegar produced by the destructive

(1) Ure's Dictionary of Arts and Manufactures.

distillation of wood, but as the formation of this acid does not resemble that of acetic, we must refer to PYROLIGNEOUS ACID.

Vinegar is manufactured by one of two distinct methods, called the *slow* and the *quick method*, the one requiring months, and the other days for the completion of the process. We will first describe the manufacture by the slow method.

In countries where much wine is grown, vinegar is manufactured chiefly or entirely from the inferior sorts, and from the refuse of the wine-grower. Orleans in France is celebrated for its vinegars. The acetous fermentation is carried on in casks, called *mothers*, of about the capacity of an old English hogshead, laid horizontally on tressels, in ranks close together. Each cask has two holes at the upper part of the front end: one two inches in diameter, for pouring in the charge and drawing off the vinegar; the other of smaller size, for allowing the air to escape while the charge is being poured in by means of a funnel, which fills the large hole. The charge occupies about two-thirds of the cask. The wine is clarified before being poured into the casks, by being strained through a tun filled with chips of beechwood, well pressed down. Should the vinegar not be perfectly clear, it is filtered in a similar manner. The fermenting room is kept at a steady temperature of 86°, by means of brick flues, or hot-water pipes, running along the sides of the floor, the furnace being on the outside to prevent any contamination of the vinegar from smoke or dust. The air of the fermenting room is renewed by moderate ventilation, but the air holes are shut in windy weather, or when the temperature is too low. To see whether the fermentation is complete, a white stick, bent at one end, is plunged into the liquor. If on drawing it out it be covered with a white, thick, pearly froth, the acetification is considered complete; if the froth be red, it is not complete, in which case fresh wine is added, or the temperature is raised. This method occupies several weeks.

In the United Kingdom, vinegar is almost exclusively manufactured from malt. A sweet wort is obtained by mashing the malt as in brewing; [See BREWING;] a ferment is added, and the *wash* or *gyle*, as it is then called, is acetified either by *stoving* or *fielding*. By the first method, casks containing the wash are arranged in close rooms, heated by steam-pipes or stoves. By the second method, the casks, each containing rather more than 100 gallons, are placed on their sides in the open air, with the bung-holes up, and arranged in long parallel rows, two or more deep, with narrow walks between, forming what is called a field. These casks are supplied by means of a flexible pipe or hose, in connexion with the great wash-tun in the brew-house. The wash usually requires several months for its complete acetification, during which time the bung-holes are left open in fine weather, but covered with a tile during rainy weather. When the acetification is complete, the vinegar is removed from the casks by means of a syphon into a shoot on the ground, whence it is pumped into a store vat within doors. Before the vinegar is fit for the market, it is clarified by being passed slowly and repeatedly through

Fig. 8. VINEGAR FIELD

large vats, called *rapes*, which contain a compact heap of the stalks and skins of raisins, called *rape*, the refuse of the British wine manufacture. In order to obtain a constant supply of this article, the malt-vinegar making is associated with the manufacture of British wines, called *sweets* by the excise.[1]

In some places a solution of sugar is used in vinegar making, instead of an infusion of malt. One recipe directs 1 part of sugar to be dissolved in 6 parts of water, to which 1 part of brandy or other strong spirit is to be added together with a little yeast. This mixture is poured into a large cask with the bung-hole left open, and kept at a temperature of from 70° to 80°. The acetification will be complete in a month or six weeks, when the clear vinegar may be drawn off. Liebig recommends a mixture of 100 parts water, 13 brandy, 4 honey, and 1 of tartar; or 120 water, 12 brandy, 3 brown sugar, 1 tartar, and half a part of sour dough, to be left for some weeks in a warm place.

It is not necessary to give any further details respecting the slow method, which is very inferior to the quick method now to be described. This has been carried to such a point of perfection, that it is scarcely possible to imagine any further improvement; for the highest aim of the manufacturer, the conversion of the alcohol into acetic acid without loss, and in the shortest possible time, seems to have been completely accomplished. This method originated with Boerhaave, long before the true chemical theory of the formation of vinegar had been obtained. He employed in the manufacture two large casks of the same size, each open at the top, and placed upright on the frame of the vinegar-room. These vessels were filled with the stalks and husks of grapes, and

(1) A detailed account of Messrs. Beaufoy's Vinegar and British-Wine Factory will be found in one of Mr. Dodd's amusing Factory Visits, in the Penny Magazine, No. 679.

one was then entirely filled with the alcoholic liquor combined with the acid ferment, and called the *vinegar mixture*, and the other cask was only half filled. After 12 hours, half the liquor was drawn out from the full cask, and poured into the other, and this process was repeated every 12 hours. The acetification proceeded with great rapidity in the vessel that was only half full, as was evident from the escape of suffocating fumes of vinegar; the temperature within it far exceeded that of the vinegar room, while in the full cask it was scarcely if at all higher. An improvement on this method consisted in changing the liquors in the two casks every 3 or 4 hours instead of 12, and it was found that in the course of 14 days, such a vinegar was obtained as would have required some months by the slow method. The effect of this contrivance will be evident, when it is considered that every particle of the alcohol in the mixture must be brought into contact with the oxygen of the air, in order to be converted into vinegar, and that the porous mass formed by the grape husks presented an enormous surface to the air in the half filled cask, so that in slowly filtering through it, the mixture was broken up and divided, and the points of contact with the air multiplied to an indefinite extent. In the full cask, on the contrary, the air was in contact with the liquid only at the top of the cask; hence it will be understood why the acetification proceeded much more slowly in the full cask than in the one only half filled, for in the latter case the surface of the liquid was covered by a wet acid spongy mass full of air, and in filling it up, this mass was well washed of its acid particles, and the air renewed. The heat, also, which by the old method was maintained at great expense of fuel, was by the new method generated during the rapid acetification of the mixture, the heat thus liberated being usefully employed to maintain the temperature of the mixture. For example, in converting 10 lbs. of alcohol into vinegar, the same amount of heat is liberated, whether the change be slow or rapid; but in the one case it is distributed over a larger portion of time—say fifty days, and that 500° of the heat of temperature is set free. In such case there would be an accession of heat to the mixture, amounting to only 10° per day, and this would probably be carried off by the surrounding air. But if the fifty days were by the quick method reduced to ten, the mixture would have the heating effect of 50° per day; and if this 10 days were reduced to 1 day of 12 hours, it would have the whole 500° in that time, which would be at the rate of $41\frac{2}{3}$° per hour, which could not all be dissipated into the surrounding air, so that the mixture could be maintained at a tolerably high temperature without any or much assistance from artificial heat.

Boerhaave's plan has been carried to its greatest point of perfection by a new method of constructing the casks. They are now made of oak, and are from 5 to 7 feet high, and from $2\frac{1}{2}$ to 3 feet in diameter, but somewhat narrower at the bottom than at the top. About a foot from the bottom, and just above the syphon *f* used for drawing off the acid liquor, each tub is perforated by holes *a* about an inch wide, and sloping downwards, so that the air may enter without allowing the liquor to escape. Each tub is closed by a cover, with a hole in the centre 2 or 3 inches square. Instead of the grape husks and stalks before noticed, each cask is filled with curled beech shavings; but before they or the casks are used, they are repeatedly scalded with hot water to get out all soluble matters, and when dried, are imbued with hot vinegar. The casks are ranged on wooden frames or brick piers sufficiently high to allow the liquor to be conveniently drawn off.

Fig. 9.

According to another arrangement the cask, A (Fig. 9), called a *graduation vessel*, is furnished with an inner hoop of beech-wood (*c*), about six inches from the mouth (*d*), supporting a perforated shelf. Through the perforations, which are numerous, cotton wicks are drawn and secured by a knot at the upper extremities; they are just thick enough to allow the liquid poured upon the shelf to pass through and drop from their lower ends. The edges of the shelf are packed with tow to prevent the escape of liquid at the side. The lower compartment is filled with beech-wood shavings nearly up to the ends of the wicks. By this means the vinegar mixture is divided into drops, and thus exposed more intimately to the oxygen of the air of the cask.

The vinegar mixture consists of 20 quarts alcohol, 40 of vinegar, and 120 water; or $15\frac{1}{2}$ quarts alcohol, 20 vinegar, and 137 water. The water is first heated to 100° or 104°, and then the vinegar and alcohol are added, so that the temperature of the mixture may be about 86° or 90° before it is poured into the casks. From $2\frac{1}{2}$ to 5 quarts of the mixture, according to the size of the casks, are poured upon the shavings every half hour. The cover is then put on, but the hole in the centre is left open. When all the mixture has filtered through, the liquor is drawn off into the mixing vessel, and a few quarts of alcohol are added; it is passed a second time through the shavings, then drawn off and a smaller quantity of alcohol added; it is then sent through the shavings a third time. The liquor after the first percolation becomes changed into a weak vinegar; after the second percolation it becomes greatly increased in strength; and after the

third, it is perfectly good and very strong vinegar. The reason why the alcohol is not added all at once, is, that even under favourable circumstances a portion of the alcohol escapes the acetifying action. Indeed in some cases the manufacturer finds that all his alcohol has disappeared, and that no vinegar has been produced. This may occur when the supply of air has not been sufficient to allow the alcohol to be converted into acetic acid. In such case the alcohol becomes transformed into aldehyde, which being extremely volatile, (its boiling point being 72°,) escapes, and leaves nothing but water in the cask. Hence the supply of air to the cask should be abundant, and this is the object of perforating the cask near the bottom, and having the hole in the cover open. If all goes on favourably, the vinegar is rapidly formed, and the temperature rises. With a vinegar room at 77°, and the mixture at 82°, the interior of the casks will often be 95° or 100°. The internal temperature of the casks should not be less than 95°, or the vinegar mixture will not *breathe* enough oxygen. The escape of heat from the casks is prevented by covering them with paper or linen jackets; the air-holes being of course left open. In general it may be remarked that the higher the temperature, and the larger the quantity of air conveyed in the shortest time to the mixture, the more rapidly is the hydrogen of the alcohol oxidised and vinegar formed. The more alcohol there is in the mixture, the stronger will be the vinegar; but the quantity of alcohol in the mixture ought not to exceed 10 per cent. The temperature must not be below 72° nor above 113°. When fruit or malt vinegar is prepared by this process, the liquor must be as clear as possible, or the shavings will become coated with a slimy substance.[1]

There is another quick process of making vinegar which has been partially introduced into this country. This plan, which was patented in 1824, by Mr. Ham, of Norwich, differs in many respects from the process just described. The apparatus consists of a large vat, in the centre of which is a revolving pump, having two or more shoots pierced with holes so as to cause a constant shower of wash to descend from the top. The lower part of the vat contains the wash, and in the upper part are birch twigs properly prepared and arranged so as not to interfere with the revolving shoots. Between the surface of the wash and the joists which support the birch, is a vacant space of 3 or 4 inches, into which air is let or forced by holes made in the vat. By means of steam pipes the wash is maintained at the temperature of from 90° to 100°, and being kept in motion by the constant action of the pump, it is so fully exposed to the oxygen of the air in trickling through the twigs, that it becomes acetified in the course of 48 hours; but in practice, it is usual to occupy from 15 to 20 days, according to the season and the state of the atmosphere, in obtaining the complete acetification of the charge.

(1) Chemical Gazette, Vol. i. Rose, Lectures on Organic Chemistry. Otto, Lehrbuch der rationelle Praxis.

In 1841, a patent was taken out by Mr. Neale, and others, for the manufacture of vinegar from beet root. The roots are reduced to pulp, and the saccharine juice extracted by pressure. Water is added to the juice, and the whole is boiled. It is next cooled to 60°, and fermented with yeast. The fermented wash is pumped into an acidulating vessel, which is a strong vat of the capacity of 24,000 gallons, in the centre of which, near the bottom, is a small inverted dome, pierced with a multitude of holes, and connected with a blowing apparatus outside. The temperature of the wash is maintained by a coil of steam pipe within the vat, and the interior of the vat is divided into several compartments by means of false bottoms pierced with small holes. The cover is furnished with a valve opening outwards, which yields to a slight internal pressure from the air within.

The total number of vinegar factories in the United Kingdom was, a few years ago, only 48, of which the 5 principal were in London. Vinegar is known in commerce by the numbers 18, 20, 22, and 24, which originally represented the number of pence per gallon, at which it was sold; but these numbers now represent merely a certain quality of the article. About 3,000,000 gallons of vinegar are annually manufactured in the United Kingdom, of which quantity more than half is made by four London firms. An excise duty of 2*d.* is levied on every gallon of proof vinegar, which is represented by No. 24; this, at the specific gravity of 1.0085, contains 5 per cent. of real acid. Vinegar is sometimes made double proof, and then pays 4*d.* per gallon duty. The strength may be estimated by a species of HYDROMETER, called an *acetometer*, but as the specific gravity of vinegar depends more upon foreign matters than upon the actual quantity of acetic acid contained in it, the best method is to saturate a given quantity of the vinegar with dry carbonate of soda; and the quantity of that salt required for the purpose indicates the proportion of real acetic acid present, 54 parts of dry carbonate of soda being equivalent to 51 of true, or anhydrous acetic acid. Another method is to saturate the vinegar with lime. "The equivalent of carbonate of lime, which is 50, is so near that of acetic acid, as to furnish a ready mode of ascertaining the value of vinegar, or other dilute acetic acid. For this purpose a piece of clean white marble is selected and accurately weighed; it is then suspended by a thread in a proper quantity of the vinegar to be examined, which is occasionally cautiously stirred, so as to mix its parts without chipping the marble; when it is no longer acted on, it is removed, washed, dried, and weighed; its loss is equivalent to the acetic acid."[1]

Vinegar may be made stronger by exposure to a low temperature, for the aqueous portion freezes first, and may be removed; and the part which remains unfrozen will be found to be greatly increased in strength.

The quantity of real acid in vinegar is difficult to ascertain, from its being often adulterated with sul-

(1) Brande's Manual of Chemistry, p. 1717.

phuric, nitric, and hydrochloric acids. Indeed the manufacturers are allowed by law to mix one thousandth of sulphuric acid with the weight of the vinegar. The presence of sulphuric acid may be detected by nitrate of baryta, which occasions a white precipitate. Nitric acid is present, if a bit of gold leaf, wetted with hydrochloric acid, be dissolved on gently heating a portion of the vinegar in a watch glass. Hydrochloric acid is present, if a white precipitate be produced on adding a solution of nitrate of silver to the vinegar. Pepper, and other acrid substances used to adulterate vinegar may be detected by neutralising the vinegar with carbonate of soda, when their undisguised pungency will detect them. Vinegar is apt to be infested with flies *(Musca cellaris)*, and with animalcules commonly termed *eels (Vibrio aceti)*; these may be destroyed by passing the vinegar through a spiral tube immersed in boiling water. Vinegar exposed to the air gradually becomes turbid or *mothery;* it loses its acid, and deposits a slippery gelatinous substance, which when dried resembles gum. The vinegar becomes weak and mouldy as this change goes on.

The use of vinegar as a condiment may be understood from the properties of acetic acid. In its concentrated state, this acid acts on living tissues as a caustic, producing heat, redness, and rapid inflammation of the skin. It dissolves many organic products, such as camphor, gluten, gelatine, gum resins, resins, fibrine of blood, white of egg, &c. When properly diluted, as in vinegar, and used in moderation, it promotes digestion. The property of the acid in dissolving gelatine shows the use of vinegar as a condiment with veal, young meats, and fish. It also assists the digestion of crude vegetables, such as salads. Its powers are heightened by having aromatic or pungent substances dissolved in it, such as chilies or tarragon. Persons who use much vinegar with the view of preventing corpulency, may do themselves much injury, and even engender cancer in the stomach. The *salts of vinegar* sold at the druggists' shops as a reviving scent in sickness and fainting, consist of sulphate of potash impregnated with acetic acid, and scented with oil of rosemary, or lavender.

A pure variety, called *distilled vinegar*, was formerly produced by distilling common vinegar, a plan now almost entirely superseded by mixing pure acetic acid with water. Colour can be imparted to it by means of burnt sugar.

ACIDS (Lat. *acidus*, sour) form a very numerous and important class of bodies in chemistry, and in many of those arts and manufactures in which chemical processes are concerned. Perhaps the most important acid in a manufacturing point of view is the SULPHURIC. NITRIC, HYDROCHLORIC, ACETIC, CARBONIC, TARTARIC, CITRIC, OXALIC, ARSENIOUS, and other acids, are also important objects of commerce.

The common idea of an acid, is a soluble substance possessing the property of *sourness*. The chemist, however, disregards this property, and considers all those substances to be acids which impart a red colour to blue litmus paper, and form stable, neutral and crystallizable compounds with *bases*, such as alkalies and earths, or metals or their oxides. Indeed, all acids are remarkable for their great powers of combination. Many acids are natural or organic products, of very complex structure: these cannot be formed synthetically, that is, by artificially uniting their elements; others are not found in nature, but result entirely from chemical processes. Acids occur in all three kingdoms of nature: phosphoric acid is found in bone; citric and oxalic acids are vegetable products, and chromic and arsenic are of mineral origin. Those acids which are produced by the oxidation of a metal, are termed *metallic* acids.

The states and properties of acids are of the most varied description; some are gaseous, as carbonic acid; others fluid, as nitrous; others solid, as tartaric: some cannot exist except in combination with water or with a base, such as acetic; others exist without either, as anhydrous sulphuric acid. Most of the acids are colourless, but chromic acid is red; some are inodorous, as sulphuric; others pungent, as hydrochloric: some are comparatively fixed, as the phosphoric; others can be converted into vapour at a moderate heat, as sulphuric; others are volatile at all temperatures, as the hydrochloric.

No simple or elementary substance has the properties of an acid. Hence all acids are compounds of two or more elements. When oxygen was first discovered, it was observed that by its union with phosphorus, sulphur, nitrogen, &c. acids were produced; hence it was supposed that oxygen was the principle of acidity, and it was named accordingly *acid-producer*, from ὀξὺς, acid, and γεννάω, I generate or produce. But when it was discovered that the union of oxygen with an element produced in some cases an alkali instead of an acid, and that muriatic and some other acids contained no oxygen at all, this theory was abandoned, although the name of oxygen was retained.

The union of one elementary substance with another, is termed a *binary compound;* as for example, oxygen with sulphur in sulphuric acid, or oxygen with sodium in soda. Combinations of binary compounds with each other, as of sulphuric acid with soda, are termed *ternary* compounds; three elements being concerned, as in the instance just given, viz. sulphur, oxygen, and sodium. Most of the mineral salts are ternary compounds. Combinations of salts with one another, or double salts, such as alum, are named *quaternary* compounds.

In binary compounds of oxygen which possess acid properties, the name of the acid is derived from that of the substance which combines with the oxygen, with the termination *ic*. When the same element forms two acid compounds with oxygen, the term *ous* is applied to that which contains the less proportion of oxygen, as in sulphurous and sulphuric acids. When these acids combine with bases to form salts, the *ous* of the acid is changed into *ite*, and the *ic* into *ate*. Thus a salt of sulphurous acid is a *sulphite;* of sulphuric acid, a *sulphate*.

This sort of nomenclature served to distinguish these acids and their salts until, as chemistry advanced, an acid was discovered containing less oxygen than the sulphurous, and then a new name was required: it was therefore called *hyposulphurous* acid, and the salt formed with it was termed a *hyposulphite*, (from the Greek ὑπὸ, under;) so also when an acid was discovered containing less oxygen than the sulphuric but more than the sulphurous, it was called *hyposulphuric* acid, and its salt a *hyposulphate*. In some cases acids have been discovered containing more oxygen than those already named with terminations in *ic*: to these the prefix *hyper* (from the Greek ὑπὲρ, over) is attached, as *hyperchloric* acid, and its salts *hyperchlorates*. A similar system is adopted for all analogous acids.

There is a class of acids called *sulphur acids*, in which sulphur takes the place of oxygen. In such cases the names of the corresponding oxacids are sometimes applied to them with the prefix *sulph*; as sulpharsenious and sulpharsenic acids, which resemble arsenious and arsenic acids in composition, but contain sulphur instead of oxygen.

Most acids contain either oxygen or hydrogen; those which contain the former are termed *oxygen acids* or *oxyacids*; those which contain the latter are named *hydrogen acids* or *hydracids*. Oxygen, as already stated, combines with the same element in various proportions, forming several distinct acids therewith; but hydrogen does not combine with the same element to form more than one acid. In the nomenclature of the hydracids, the names of both constituents are usually given:—thus the acid compound of hydrogen and chlorine is named *hydrochloric* acid, (a more systematic term than the name *muriatic*, formerly applied to it;) the acid compound of hydrogen and sulphur is named *hydrosulphuric* acid, and so on. The salts of these acids are termed hydrochlorates and hydrosulphates. The subject of salts will be taken up more in detail hereafter. The processes concerned in the manufacture of the most important commercial acids, will be found under the respective heads indicated at the commencement of this article.

ADHESION. The force by which two dissimilar substances resist separation, although their contact does not produce any permanent change in them. It is distinguished on the one hand from COHESION, which is applied to a force of the same kind between similar substances, or parts of the same body; and on the other hand from AFFINITY, which acting between dissimilar substances, not only resists their separation, but renders it impossible by mere mechanical force.

The undisguised action of adhesion generally requires one of the bodies to be solid, because if both were fluid they would mix, and the phenomenon would come under the head of affinity. On the other hand, it commonly requires one body at least to be soft, plastic or semifluid if not fluid, for when both are completely solid we know of no case of decided adhesion which is not referable to electrical or magnetic attraction, or the pressure of the air or other surrounding fluid. Two pieces of clean lead, or of glass, adhere independently of these causes, *i. e.* by the action of cohesion; but with dissimilar metals or other hard bodies, however we may press them, no such phenomenon occurs, for the removal of the atmospheric pressure causes them to fall asunder. Hence it would appear that the "attraction of adhesion," as it has been called, is limited to shorter distances than that of cohesion; since two pieces of the same hard solid can be brought near enough to cohere, while two different solids, no harder or more rigid, cannot be brought near enough to adhere. To produce adhesion generally requires one of the solids to be rendered by heat semifluid or ductile, and then its return to a hard state (if not attended with crystallization) does not diminish the adhesion, unless the unequal contractions of the two substances, by the same fall of temperature, force them to separate. Hence the fitness of different cements to join different substances, depends mainly on their equal expansibility by heat. Metals, being more expansible than solids in general, will not adhere to ordinary cements, but require metallic ones (called solders); and each of these does not adhere to all metals indifferently, but only to those having nearly the same rate of expansion. Glass and stones, being both less expansible and less various in their rates of expansion, adhere to a greater variety of substances; and light porous solids, being very little affected by change of temperature, adhere still more generally to those of the same kind which may be softened by heat or liquid solvents, and return to the solid state gradually and without tendency to crystallize. The most universally adhesive bodies (as pitch) are those which retain, even at low temperatures, a certain ductility by which they may readily yield to the various expansions and contractions of the rigid bodies in contact with them; and the rigid bodies most readily made to adhere are the worst conductors of heat; because they cannot undergo very sudden changes of temperature or of bulk, and so allow time for the adhering body to accommodate itself. The non-adhesiveness of animal membranes is very remarkable, and probably a provision for their cleanliness and freedom from foreign matter. Crystallization, by requiring a body while solidifying to obey with rigour certain internal laws of its own, is a great bar to adhesion.

The adhesion of two solids is generally stronger than the cohesion of at least the weaker one. Hence if two pieces of wood be glued, gummed, or pasted together, and then separated, a layer of cement adheres to each; and if there be a bank note in the midst of the cement, it will be split into two layers, simply because its own cohesion is less than that of the cement, or of the wood, or the adhesion between the cement and either wood or paper. [See CEMENTS, MORTARS, and SOLDERS.]

The adhesion between a solid and liquid is often greater than a cohesion of the liquid, so that on separating them a film of liquid remains attached to the solid, and it is said to be *wetted*. Aëriform fluids

will *wet* as well as liquids. Thus on plunging the finger (or any non-metallic body) into mercury, it does not touch that liquid, but retains a film of air; just as it would retain, in air, a film of water with which it had been wetted. Some few bodies, generally of a fatty nature, adhere to air in preference to water, and thus cannot be wetted by the latter, except in vacuo, or when plunged to a great depth. Iron requires the pressure of a certain small depth of water to remove its air-film, for small particles of it, and even a needle, carefully placed on water, retain air enough to float them. A body plunged from air into a liquid may behave in three different ways. If its attraction for the liquid be such as to overcome both the adhesion of the air and the cohesion of the liquid, it will raise the liquid all round it with a concave slope, as happens with silver dipped into mercury, or perfectly clean glass into water, but such cases are not common. If the attraction for the liquid be not sufficient to overcome the adhesion of the air, the liquid will be depressed, with a convex slope, to that depth at which its hydrostatic pressure enables it to expel the air-film; and yet after once touching the solid, it may adhere thereto with force enough to overcome its own cohesion, and so may wet it. This is the commonest case with water, and it occurs also with platinum dipped into mercury. The third case is when the adhesion of the solid to the liquid being weaker than the cohesion of the latter, it cannot be wetted even though the intervening air-film be expelled. This occurs with iron, brass and cobalt made to touch mercury; and even in such cases adhesion is not absent, and is more easily measured than in any other case. Guyton-Morveau took disks of these metals 1 inch in diameter, and having suspended them from one arm of a balance, and counterpoised them by weights, made them touch the surface of mercury, when it required the addition to the other scale of 115 grains, 142 grains, and 8 grains to detach them. Gay-Lussac found that when such disks can be wetted by the fluid, they always require (with the same fluid) the same force, however different their materials may be, for this does not measure their adhesion but only the *cohesion* of the fluid, a film of which has to be torn from the rest. But in the case of mercury and metals wetted by it, Morveau found various forces necessary to detach them, because *affinity* is here concerned, for the adhering film is not pure mercury, but an amalgam of the two metals, and the force measured is either the cohesion of this amalgam, or its adhesion to the pure mercury, or to the more liquid amalgam left behind. He found these forces nearly proportional to the affinities of the metals for mercury, or the readiness with which they combine with it; and adhesion may doubtless be considered proportional to, or even identical with that kind of affinity to which the term affinity is most proper, because it acts most between bodies having some resemblance; but both this and adhesion are totally independent of the force commonly called affinity by chemists, which acts most between bodies widely differing from each other. This distinction must be borne in mind, and for this purpose, besides the difference above mentioned there are two others equally broad and important: the affinity that bears a relation to adhesion produces compounds whose properties are in every respect *intermediate* between those of the ingredients, as alloys, solutions, &c.; but the other affinity produces compounds with new properties unlike either of the ingredients, as oxides from a gas and a metal, salts from acids and alkalies, &c.; and lastly, the former kind of affinity produces compounds in which the proportions of the ingredients may vary, as sugar and water in syrup, copper and zinc in brass, &c.; while the other kind leads to definite compounds, whose proportions are always the same. [See AFFINITY.]

For a further account of the effects resulting from the adhesion of liquids to solids, see CAPILLARITY.

ADIT, a passage or entrance, (Latin *aditus*, from *ad-ire*, to go to.) [See MINE.]

ADJUTAGE. [See HYDRAULICS.]

ADZE or ADDICE, a cutting tool or percussive chisel with a thin arching blade, and its edge at right angles to the handle. In the AXE the edge is in the same plane with the handle. These tools are always used with percussion, and hence differ from chisels, which act by pressure. The axe differs from the adze in being a splitting wedge, not a cutting instrument; for if driven into a block of wood as at *a* (Fig. 10) it will split it into two parts through the natural line of the fibres, leaving rough uneven surfaces, and the rent will precede the tool. A similar effect will be produced on removing a stout chip from the side of a block of wood with the hatchet, adze, or paring chisel. So long as the chip is too rigid to bend to the edge of the tool, the rent will precede it. If the instrument is thin and sharp, so that the shaving can bend to the tool, the wood will not split; it will be *cut*. In paring tools, one face of the wedge or tool is nearly parallel with the face of the work. In tools ground with only one chamfer this position not only assists in giving direction to the tool, but also places the strongest line of the tool in the line of resistance, or of the work to be done. Thus the axe or hatchet with two bevils *a*, which is intended for hewing and splitting and not for cutting, must, when required for the purpose of paring the surface, be applied at the angle *a′*, which is a much less convenient and effective position than (*b*) that of the side hatchet with only one chamfer; but for paring a large or a nearly horizontal surface, the side hatchet is inferior to the adze *c*. This instrument is held in both hands by the handle, which is from 24 to 30 inches long, while the operator stands upon his work in a stooping position. The weight of the blade is from 2 to 4 pounds. "The adze is swung in a circular path almost of the same curvature as the blade, the shoulder-joint being the centre of motion, and the entire arm and tool forming as it were one inflexible radius; the tool therefore makes a succession of small arcs, and in each blow the arm of the workman is brought in contact with the thigh, which thus serves as a stop to prevent accident. In coarse preparatory works, the workman

directs the adze through the space between his two feet; he thus surprises us by the quantity of wood

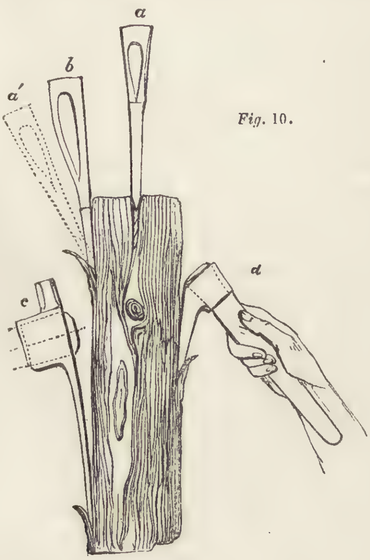


Fig. 10.

removed. In fine works he frequently places his toes over the spot to be wrought, and the adze penetrates 2 or 3 inches beneath the sole of the shoe, and he thus surprises us by the apparent danger, yet perfect working of the instrument, which in the hands of the shipwright in particular, almost rivals the joiner's plane. It is with him the nearly universal paring instrument, and is used upon works in all positions."[1]

The small Indian adze or Bassoolah *d*, instead of being circular like the European adze, is formed at a direct angle of 45° or 50°. Its handle is only 12 or 13 inches long, and the tool is used with great precision by the motion of the elbow joint. It is grasped so near the head that the forefinger rests on the metal, the thumb nearly on the back of the handle, the other fingers grasp the front of it, the nails approaching the ball of the thumb. The wrist is held firmly, the stroke being made principally from the elbow, tne inclination of the cutting face being nearly a tangent to the circle described by the instrument round the elbow joint as a centre, the exact adjustment being made by the grasp and the inclination of the wrist, which is soon acquired by a little practice. In this way very hard woods may be dressed for the lathe, with a degree of ease and accuracy not attainable with the small axe used in this country.

In order to grind any one of the adzes just noticed the handle must be removed, and this is easily done, as the eye of the tool is larger externally than internally, as in the common pickaxe, so that the tool cannot fly off when in use, but a blow on the end of the handle easily removes it.

ÆOLIPILE, (from *pila Æoli*, the ball of Æolus, or of the god of the winds,) an instrument formerly used to illustrate the cause and generation of the wind, although it is simply an instrument for converting water into steam. It consists of a hollow ball of metal sometimes made in the form of a human face in the act of blowing, with a slender pipe with a narrow orifice issuing from the mouth of the figure, or inserted into the ball by means of a shouldered screw. The ball being filled with water and the pipe screwed in, the flame of a spirit lamp or the heat of burning charcoal is applied to it, and the water being heated, high pressure steam is formed, which escapes with a great noise from the jet, and with sufficient force to turn round a small vaned wheel opposed to it. Of course the stronger the heat the more elastic and violent will be the steam. Care must be taken that the jet is not stopped up, or the ball may burst and lead to danger. The æolipile is now regarded as only a scientific toy of no practical use, and of very little use to the scientific lecturer, who has better means at his disposal for illustrating the generation and force of steam.

AERATED WATERS. [See Carbonic Acid—Soda Water.]

AEROSTATION and AEROSTATICS, standing in the air, from ἀήρ, the air, and ἵστημι, to stand, or στάσις, standing. AERONAUTICS, sailing in the air, from ἀήρ, the air, and ναῦς, a ship. This subject ought scarcely to find a place in a work devoted to the useful arts, because aërostation has rarely been applied to any useful purpose. The art of flying in the air had been a favourite problem with learned and scientific men from the times cf antiquity; but there is no authentic account of the problem having been solved until towards the close of the last century, when the brothers Montgolfier invented a machine which they called a *ballon* or little ball, from which we derive the word balloon. About the same period Cavendish, in England, discovered hydrogen gas, and proved it to be the lightest of all ponderable substances; it therefore occurred to Dr. Black, in 1767 or 1768, that a light envelope filled with this gas would ascend. The experiment was tried by Cavallo, in 1782, but he did not succeed in causing anything heavier than a soap-bubble to ascend. The first balloon that was actually launched into the air, was constructed by Stephen and Joseph de Montgolfier, paper-makers at Annonay, near Lyons. It occurred to them that a thin paper envelope might be employed to confine hydrogen gas in such a way as to cause it to ascend, but they found that the gas escaped so rapidly through the pores of the paper that it could not be depended on. They then conceived the idea that heat might be employed to rarefy the air enclosed in their balloon. The experiment was tried, and a balloon of coarse linen, lined with paper, of the capacity of 23,000 cubic feet, (French,) was found to have a power of lifting about 500lbs. including its own weight. This trial was so successful that the Montgolfiers thought they had completely solved the celebrated problem of flying or sailing in the air. They even suggested that "large balloons might be employed for victualling a besieged town,

(1) Holtzapffel on Turning and Mechanical Manipulation, vol. ii. London, 1847.

for raising wrecked vessels, perhaps even for making voyages, and certainly in particular cases for observations of different kinds, such as reconnoitring the position of an army,[1] or the course of vessels at 25 or even 30 leagues distance, &c." A public exhibition was made of a *montgolfière*, (as this kind of balloon was called, to distinguish it from the hydrogen-gas balloon,) in the market-place of Annonay, on the 5th June, 1783. The montgolfière was constructed of immense folds of linen buttoned together, and fixed to a frame 110 feet in circumference, the whole weighing about 500lbs., and containing 22,000 cubic feet (French) of air. On applying fire to the opening at the bottom of the balloon, the mass gradually swelled out into a large globe, and was with difficulty prevented from rising. At length it was liberated, and rose with great rapidity. In less than 10 minutes it gained an elevation of 1,000 toises. It then moved in a horizontal line, and gradually descended. The success of this experiment excited the greatest interest all over Europe, especially in Paris, where it was immediately resolved to repeat the experiment with hydrogen gas instead of heated air. A balloon was formed of lutestring, and varnished with India rubber, and on the 23d August it was filled with hydrogen gas, procured by the action of dilute sulphuric acid and iron filings. Considerable difficulty was experienced in filling it; but the gas not having been washed by passing it through cold water, entered the balloon hot, and charged with acid fumes, so that it injured the envelope, and loaded it with moisture. As much as 500lbs. of sulphuric acid, and twice that weight of iron filings were expended before the balloon was completely filled. At length it rose, and was kept suspended at the height of 100 feet above the ground. In this state it was conveyed with acclamations to the Place des Victoires, and about midnight it was transported in silent procession to the Champ de Mars, proceeded by torches, and guarded by horse and foot soldiers; the people were filled with astonishment, and many of them saluted it respectfully as it passed. On the 27th, it was again filled, and allowed to ascend. It remained three-quarters of an hour in the air, and fell five leagues from Paris. On the 19th September, one of the Montgolfiers being in Paris, sent up one of his balloons with an attached car containing a sheep, a cock and a duck. These were therefore the first aërial voyagers. M. Pilatre de Rozier was their immediate successor, but he deemed it prudent to have a rope attached to the balloon and held by persons below, so that he might not be entirely launched into the air. At length, on the 21st November, 1783, this gentleman, accompanied by the Marquis d'Arlandes ascended in a montgolfière at 1.54, P. M. "It rose in the most majestic manner, and when it was about 270 feet high, the intrepid voyagers took off their hats and saluted the spectators. No one could help feeling a mingled sentiment of fear and admiration. The voyagers were soon undistinguishable, but the machine, hovering in the air, and displaying the most beautiful figure, rose at least 3,000 feet high, and remained visible all the time. It crossed the Seine below the barrier of La Conférence; and passing thence between the Ecole Militaire and the Hôtel des Invalides, was in view of all Paris. The voyagers, satisfied with their experiment, and not wishing to travel further, agreed to descend; but seeing that the wind was carrying them upon the houses of the Rue de Sève, Faubourg St. Germain, they preserved their presence of mind, increased the fire, and continued their course through the air till they had crossed Paris. They then descended quietly on the plain, beyond the new Boulevard, opposite the mill of Croulebarde, without having felt the slightest inconvenience, and having in the car two-thirds of their fuel. They could then, if they had wished, have gone three times as far as they did go, which was 5,000 toises, done in from 20 to 25 minutes. The machine was 70 feet high, 46 feet in diameter; it contained 60,000 cubic feet, and carried a weight of from 1,600 to 1,700lbs."

The second ascent was by Messrs. Charles and Robert, on the 1st December, 1783, in a balloon filled with hydrogen.[1] They ascended from the Tuileries at Paris, and in an hour and three-quarters alighted on the meadow of Nesle, 25 miles from Paris. Finding that the balloon was still buoyant, M. Charles ventured alone upon a second ascent. The sun had set, and it was getting dark, but he ascended with great velocity, and reached a height of 2 miles in about ten minutes. The sun rose again to him in full orb, and as he says, "I was the only illuminated object, all the rest of nature being plunged in shadow." A screen of vapour concealed the earth from view, while the moon scattered gleams of variou hues over the fantastic and changing forms of the clouds beneath. The air was very cold; the balloon appeared to be fully distended, and upon opening the valve, the gas rushed out like a misty vapour. He descended slowly, and alighted in safety near the forest of Tour du Lay, having travelled 9 miles in 35 minutes. The barometer at the greatest elevation fell to 20.05 inches, giving an elevation of about 9,700 feet. The thermometer sank to 21° Fahr. A short time before this ascent, a small pilot or messenger fire-balloon was launched by Montgolfier; this was found to have proceeded in an opposite direction, which first gave rise to the suspicion of the existence of different currents of air at different heights.

On the 2d March, 1784, M. Blanchard ascended

(1) This idea was actually practised at the battle of Fleurus in 1794, in which the French, under General Jourdan, gained a decisive victory over the Austrian forces, which has been ascribed principally to the accurate information of the enemy's movements before and during the battle, communicated by telegraphic signals from a balloon sent up to a moderate height. The aëronauts, at the head of whom was the celebrated chemist Guyton-Morveau, mounted twice in the course of the day, and continued about 4 hours each time hovering in the rear of the army. In the second ascent the enemy opened a battery against the balloon, but the aëronauts soon rose to a height above the reach of cannon.

(1) Some idea may be formed of the expense of ballooning at this early period in the history of the art, from the fact that this apparatus cost 400*l*. sterling, one half of which was expended in the production of the gas alone.

from Paris in a hydrogen balloon furnished with wings and a rudder, but they were found to be of no use in guiding the balloon. A parachute or open umbrella was attached above the car, to break the fall in case it separated from the balloon. On the 19th September of the same year, the longest aërial journey yet made was accomplished. The Duke de Chartres, afterwards Orleans, employed Robert to construct a silk balloon. It was 56 feet high, and 36 feet in diameter, its form being a cylinder terminated by two hemispheres. This balloon, which was filled with hydrogen, had a contrivance proposed by Meunier for regulating the ascent and the position of equilibrium of the balloon in the atmosphere. It consisted of a small balloon placed within the principal one, and filled occasionally with common air by means of bellows, or emptied again by opening an exterior valve. The aëronaut would thus be able, without expending the charge of hydrogen gas, either to sink gently through a small space, or to rise again at his pleasure, simply by inflating the inner balloon, or allowing it to collapse. The elevation could thus be adjusted with great nicety. In the first trial of this apparatus, the duke, Messrs. Robert and Charles, and a fourth person, ascended very slowly with a force of only 27lbs., as much as 500lbs. of ballast being stored in the car. At the height of 1,400 feet a storm came on; the thermometer fell from 71° to 61°, and this cold caused the balloon to descend within 200 feet of the tops of the trees near Beauvais. Ballast was thrown out and the balloon rose to an elevation of 6,000 feet, when the gas was found to be 42° warmer than the external air. The duke being very much alarmed for his safety, and anxious to descend, is said to have pierced the lower part of the silk bag with his sword to let out the gas. After many narrow escapes from the dangers of wind and a thunder storm, the balloon descended safely near Bethune, having performed a voyage of 135 miles in five hours.

Passing over several ascents made in France and in this country, we must notice the fate of the first aërial sailor, M. Rozier. On the 15th June, 1785, in company with a young gentleman named Romain, he ascended at Boulogne-sur-Mer with the intention of reversing the experiment performed by M. Blanchard and Dr. Jeffries, who on the 30th November, 1784, crossed the Channel from Dover with the intention of landing at Calais, but after considerable difficulty, were actually deposited in the forest of Guiennes. The arrangements made by M. Rozier were as follows. In order to counteract the fluctuations consequent upon all aërial excursions under the ordinary circumstances, and to obtain the power of increasing or diminishing the weight of his apparatus at will, without the usual expenditure of gas and ballast, he conceived the idea of uniting a montgolfière with a hydrogen-gas balloon. Accordingly, he affixed to the hydrogen balloon, by which the principal part of the weight was to be borne, a small montgolfière, by acting upon which he expected to be able to alter its specific gravity as occasion might require. M. Rozier, however, does not seem to have taken into account the great expansion which a gas undergoes under diminished atmospheric pressure, such as is experienced on ascending to a great height; for as the machine rose

Fig. 11. MONUMENT TO MM. ROZIER AND ROMAIN.

the inflammable gas gradually distended the envelope in which it was contained, and then, not having room for further expansion, poured down the tube which formed the neck of the balloon, and speedily reaching the fire used to inflate the montgolfière, became ignited. The whole apparatus was consumed in the air, and the two unfortunate voyagers were precipitated upon the rocks near the sea-shore. A monument was erected on the spot where they fell; it is now in a dilapidated condition, as will be seen from the engraving (Fig. 11) made from a sketch taken a few years ago by a friend of the editor. The ruinous condition of this monument is entirely due to the wanton mischief of the lower orders in the neighbourhood of Boulogne, and is sufficient, we think, to prove that public monuments when left unguarded fare no better in France than in England. The following is an exact copy of the inscription on this monument:—

"ICY SONT TOMBEZ, DE LA HAUTEUR DE PLUS DE 5 MILLE PIEDS, À 7 HEURES 35 MINUTES DE MATIN, LES INFORTUNES AÉRONAUTES, PILATRE DE ROSIER ET ROMAIN LAINÉ. PARTIS DE BOULOGNE À 7 HEURES 5 MINUTES DU MATIN DE 15 JUIN, 1785, LE PREMIER TROUVÉ MORT SUR LA PLACE, LE SECOND DONNA QUELQUES SIGNES DE VIE PENDANT UNE OU DEUX MINUTES."

It has been already stated that the French employed

balloons for the purpose of military reconnaissance. In the early part of the French revolution a balloon, prepared under the direction of the Aërostatic Institute in the Polytechnic School, and entrusted to the command of two or three experienced officers, was distributed to each of the republican armies. These balloons were of a more solid and perfect construction than the toy machines hitherto exhibited. They were filled by a far more economical method than that before adopted, namely, by passing steam of water through six iron cylinders charged with iron turnings, and heated to redness in a simple kind of furnace; the oxygen of the steam uniting with the iron, while the hydrogen gas being disengaged was first passed through a reservoir of caustic lye before it entered the balloon. By this contrivance a balloon 30 feet in diameter could be filled in about 4 hours at a very moderate expense.

As the aëronautic voyages hitherto undertaken had contributed almost no results to science, the French philosophers were anxious to employ one of the balloons of the Aërostatic Institute, for the purpose of making a set of observations in the higher regions of the air. In July, 1803, Messrs. Robertson and Lhoest had ascended from Hamburg to a height of nearly 3 miles, and had given out a statement of results, the accuracy of which had been called in question. To verify these, and also to settle other interesting points, Messrs. Biot and Gay-Lussac proposed to the French government to make an ascent. Their offer was seconded by Berthollet and Laplace, and Chaptal, then minister of the interior, gave it his warm support.[1] The balloon which had once visited Egypt was delivered to the custody of Biot and Gay-Lussac; and the same artist who constructed it was ordered to refit and prepare it under their direction at the public expense. Besides the usual provision of barometers, thermometers, hygrometers, and electrometers, they had two compasses, and a dipping needle, with another fine needle, carefully magnetized, and suspended by a very delicate silk thread, for ascertaining by its vibrations the force of magnetic attraction. To examine the electricity of the different strata of the atmosphere, they carried several metallic wires, from 60 to 300 feet in length, and a small electrophorus freely charged. For galvanic experiments they had procured a few discs of zinc and copper, with some frogs, to which they added insects and birds. It was also intended to bring down a portion of air from the higher regions, to be subjected to a chemical analysis; and for this purpose a flask, carefully exhausted, and fitted with a stop-cock, had been prepared.

The balloon was placed in the garden of the Conservatoire des Arts, and no pains were spared in providing whatever might contribute to the greater safety and convenience of the voyagers. Everything being ready for their ascent, these adventurous philosophers, in presence of a few friends, embarked in the car at ten o'clock in the morning of the 23d of August, 1804. The barometer was then at 30.13 inches, the thermometer at 61.7° Fahr., and Saussure's hygrometer pointed at 80.8°, or very near the limit of absolute humidity. They rose with a slow and imposing motion. Their feelings were at first absorbed in the novelty and magnificence of the spectacle which opened before them; and their ears were saluted with the buzz of distant gratulations, sent up from the admiring spectators. In a few minutes they entered the region of the clouds, which seemed like a thin fog, and gave them a slight sensation of humidity. The balloon had become quite inflated, and they were obliged to let part of the gas escape, by opening the upper valve; at the same time, they threw out some ballast, to gain a greater elevation. They now shot through the range of clouds, and reached an altitude of about 6,500 English feet. These clouds viewed from above had the ordinary whitish appearance; they all occupied the same height, only their upper surface seemed marked with gentle swells and undulations, exactly resembling the aspect of a wide plain covered with snow.

Our voyagers now began their experimental operations. The magnetic needle was attracted as usual by iron; but they found it impossible at this time to determine with accuracy its rate of oscillation, owing to a slow rotatory motion with which the balloon was affected. In the meanwhile, therefore, they made other observations. A Voltaic pile, consisting of twenty pairs of plates, exhibited all its ordinary effects, gave the pungent taste, excited the nervous commotion, and occasioned the decomposition of water. By rejecting some more ballast, they had attained the altitude of 8,940 feet, but afterwards settled to that of 8,600 feet. At this great elevation, the animals which they carried with them appeared to suffer from the rarity of the air. They let off a violet bee, which flew away very swiftly, making a humming noise. The thermometer had fallen to 56.4° Fahr., yet they felt no cold, and were, on the contrary, scorched by the sun's rays, and obliged to lay aside their gloves. Both of them had their pulses much accelerated. That of Biot, which generally beat 79 times in a minute, was raised to 111; while the pulse of his friend, Gay-Lussac, a man of a less robust frame, was heightened from 60 to 80 beats in the minute. Notwithstanding their quickened pulsation, however, they experienced no sort of uneasiness nor any difficulty in breathing.

What perplexed them the most was the difficulty of observing the oscillations of a delicately suspended magnetic needle. But they soon remarked, on looking attentively down upon the surface of the conglomerated clouds, that the balloon slowly revolved, first in one direction, and then returned the contrary way. Between these opposite motions there intervened short pauses of rest, which it was necessary for them to seize. Watching, therefore, the moments of quiescence, they set the needle to vibrate, but were unable to count more than five, or very rarely ten

(1) Our account of this scientific aërial voyage is condensed from Sir John Leslie's excellent notice contained in the article "Aëronautics" in the Encyclopædia Britannica.

oscillations. A number of trials made between the altitudes of 9,500 and 13,000 feet, gave 7″ for the mean length of an oscillation, while at the surface of the earth it required $7\frac{1}{20}$″ to perform each oscillation. A difference so very minute as the 140th part could be imputed only to the imperfection of the experiment; and it was hence fairly concluded that the force of magnetic attraction had in no degree diminished at the greatest elevation they could reach. The direction of this force, too, seemed, from concurring circumstances, to have continued the same; though they could not depend on observations made in their vacillating car with so delicate an instrument as the dipping needle. At the altitude of 11,000 feet they liberated a green linnet, which flew away directly; but soon feeling itself abandoned in the midst of an unknown ocean, it returned and settled on the stays of the balloon. Then mustering fresh courage it took a second flight, and dashed downwards to the earth, describing a tortuous, yet almost perpendicular track. A pigeon which they let off under similar circumstances afforded a more curious spectacle. Placed on the edge of the car, it rested a while, measuring as it were the breadth of that unexplored sea which it designed to traverse; now launching into the abyss, it fluttered irregularly, and seemed at first to try its wings in the thin element; till, after a few strokes, it gained more confidence, and, whirling in large circles or spirals, like the birds of prey, it precipitated itself towards the mass of extended clouds, where it was lost from sight.

It was difficult in those lofty and rather humid regions, to make electrical observations; and the attention of the scientific navigators was, besides, occupied chiefly by their magnetical experiments. However, they let down from the car an insulated metallic wire of about 250 feet in length, and ascertained, by means of the electrophorus, that the upper end indicated resinous or negative electricity. This experiment was several times repeated; and it seemed to corroborate fully the previous observations of Saussure and Volta relative to the increase of electricity met with in ascending the atmosphere.

The diminution of temperature in the higher regions was found to be less than what is generally experienced at the same altitude on mountains. Thus, at the elevation of 12,800 feet, the thermometer was at 51 Fahr., while it stood as low as $63\frac{1}{2}$° at the Observatory; being only a decrement of one degree for each 1,000 feet of ascent. This fact corresponds with the observations made by former aëronauts, and was probably produced by the operation of two different causes. First, the rays from the sun, not being enfeebled by passing through the denser portion of the atmosphere, would act with greater energy on the balloon and its car, and consequently affect the thermometer placed in their vicinity. Next, the warm current of air, which during the day rises constantly from the heated surface of the ground, must augment the temperature of any body which is exposed to its influence. During the night, on the contrary, the upper strata of the atmosphere would probably be found colder than the general standard, owing to the copious descent of cold portions of air from the highest regions.

The hygrometer, or rather hygroscope, of Saussure, advanced regularly towards dryness in proportion to the altitude which they attained. At the elevation of 13,000 feet it had changed from 80.8° to 30°. But still the conclusion that the air of the higher strata is drier than that of the lower, we are inclined to consider as fallacious. In fact the indications of the hygroscope depend on the relative attraction for humidity possessed by the substance employed, and the medium in which it is immersed. But air has its disposition to retain moisture always augmented by rarefaction, and consequently such alteration alone must materially affect the hygroscope. The only accurate instrument for ascertaining the condition of the air, with respect to dryness, is founded on a property of evaporation.

The ballast being now almost quite expended, it was resolved to descend. The aëronauts, therefore, pulled the upper valve and allowed part of the hydrogen to escape. They dropped gradually, and when they came to the height of 4,000 feet they met the stratum of clouds extending horizontally, but with a surface heaved into gentle swells. When they reached the ground, no people were near them to stop the balloon, which dragged the car to some distance along the fields. From this awkward and even dangerous situation they could not extricate themselves without discharging the whole of their gas, and therefore giving up the plan of sending M. Gay-Lussac alone to explore the highest regions. It has been reported that his companion, M. Biot, though a man of activity, and not deficient in personal courage, was so much overpowered by the alarms of their descent, as to lose for the time the entire possession of himself. The place where they alighted, at half-past one o'clock, after three hours and a half spent in the midst of the atmosphere, was near the village of Meriville, in the department of the Loiret, and about fifty miles from Paris.

It was the desire of several philosophers at Paris that M. Gay-Lussac should mount a second time, and repeat the different observations at the greatest elevation he could attain. Experience had instructed him to reduce his apparatus, and to adapt it better to the actual circumstances. As he could only count the vibrations of the magnetic needle during the very short intervals which occurred between the contrary rotations of the balloon, he preferred one of not more than six inches in length, which, therefore, oscillated quicker. The dipping needle had been magnetized and adjusted by M. Coulomb. To protect the thermometer from the direct action of the sun, it was enclosed within two concentric cylinders of pasteboard covered with gilt paper.

The hygrometers, which were made with four hairs, were sheltered nearly in the same way. The two glass flasks, intended to bring down air from the highest regions of the atmosphere, had been exhausted till the mercurial gauge stood at the 25th part of an inch, and their stopcocks were so perfectly fitted that after the lapse of eight days they still preserved their

vacuum. These articles, with two barometers, were the principal instruments which M. Gay-Lussac took with him.

On the 15th September, at 9.40 A.M., the scientific voyager ascended from the same place as before. The barometer then stood at 30.66 inches, the thermometer at 82° Fahr., and the hygrometer at 57½°. The sky was unclouded, but misty. Scarcely had the observer reached the height of 3,000 feet, than he observed spread below him, over the whole extent of the atmosphere, a thin vapour which rendered distant objects very indistinct. Having gained an altitude of 9,950 feet, he set his needle to vibrate, and found it to perform twenty oscillations in 83″, though it had taken 84″.33 to make the same number at the surface of the earth. At the height of 12,680 feet, he discovered the variations of the compass to be precisely the same as below; but with all the pains he could take, he was unable to determine with sufficient certainty the dip of the needle. M. Gay-Lussac continued to prosecute his other experiments with the same diligence, and with greater success. At the altitude of 14,480 feet he found that a key, held in the magnetic direction, repelled with its lower end, and attracted with its upper end, the north pole of the needle of a small compass. This observation was repeated, and with equal success, at the vast height of 20,150 feet; a clear proof that the magnetism of the earth exerts its influence at remote distances. He made not fewer than fifteen trials at different altitudes, with the oscillations of his finely suspended needle. It was generally allowed to vibrate twenty or thirty times. The mean result gives 4″.220 for each oscillation, while it was 4″.216 at the surface of the earth; an apparent difference so extremely small as to be fairly neglected.

During the whole of his gradual ascent, he noticed, at short intervals, the state of the barometer, the thermometer, and the hygrometer. Of these observations, amounting in all to twenty-one, he has given a tabular view. Leslie regrets that Gay-Lussac neglected to mark the times at which they were made, since the results appear to have been very considerably modified by the progress of the day. He also suggests that it would have been desirable to have compared them with a register noted every half-hour at the Observatory. From the surface of the earth to the height of 12,125 feet, the temperature of the atmosphere decreased regularly from 82° to 47.3° Fahr. But afterwards it increased again, and reached to 53.6° at the altitude of 14,000 feet; evidently owing to the influence of the warm currents of air, which, as the day advanced, rose continually from the heated ground. From that point the temperature diminished, with only slight deviations from a perfect regularity. At the height of 18,636 feet, the thermometer subsided to 32.9° on the verge of congelation; but it sunk to 14.9° at the enormous altitude of 22,912 feet above Paris, or 23,040 feet above the level of the sea, the utmost limit of the balloon's ascent.

Sir John Leslie thinks that from these observations no conclusive inference can be drawn respecting the mean gradation of cold which is maintained in the higher regions of the atmosphere; because the several strata are during the day kept considerably above their permanent temperature by the hot currents raised from the surface through the action of the sun's rays. Leslie had calculated that the diminution of temperature corresponding to the first part of the ascent, or 12,125 feet, ought have been 40°; but the temperature actually observed was 34.7°. In the next portion of the voyage, from the altitude of 14,000 feet to that of 18,636 feet, or the breadth of 4,636 feet, the decrease of temperature was calculated at 16¼°, whereas it was 20.7°, a proof that the diurnal heat from below had not yet produced its full effect at such a great height. In the last portion of the balloon's ascent, from 18,636 feet to 22,912, a range of 3,276 feet, the decrease of heat was calculated at 15½°, and it was actually 18°, owing most probably to the same cause, or the feebler influence which warm currents of air from the surface exert at those vast elevations. Taking the entire range of the ascent, or 22,912 feet, the diminution of temperature according to Leslie's formula would be, for the gradation of temperature in ascending the atmosphere, 85.4°. The decrease actually observed would be 67.1°, which might be raised to 80° if we admit the very probable supposition, that the surface of the earth had become heated from 82° to 94.9°, during the interval between ten o'clock in the morning, and near three in the afternoon, when the balloon floated at its greatest elevation.

It appears then from these results, that the gradation of temperature in the atmosphere is not uniform, but proceeds with augmented rapidity in the more elevated regions.

The hygrometers during the ascent of the balloon held a progress not quite so regular, but tending obviously towards dryness. At the height of 9,950 feet they had changed from 57.5°, to 62°, from which point they continued afterwards to decline, till they came to mark 27.5°, at the altitude of 15,190 feet. From this inferior limit the hygrometers advanced again, yet with some fluctuations to 35.1°, which they indicated at the height of 18,460 feet. Above this altitude the variation was slight, though rather inclining to humidity. There can exist no doubt, however, that allowing for the influence of the prevailing cold, the higher strata of the atmosphere must be generally drier than the lower, or capable of retaining, at the same temperature, a larger share of moisture.

At the altitude of 21,460 feet, M. Gay-Lussac opened one of his exhausted flasks; and at that of 21,790 feet, the other. The air rushed into them through the narrow aperture with a whistling noise. He still rose a little higher, but at eleven minutes past three o'clock, he had attained the utmost limit of his ascent, and was then 22,912 feet above Paris, being more than four miles and a quarter above the level of the sea. The air was now more than twice as thin as ordinary, the barometer having sunk to 12.95 inches. From that stupendous altitude,

1,600 feet above the level of the Andes, more elevated than the loftiest pinnacle of our globe, and far above the heights to which any mortal had ever soared, the aërial navigator calmly pursued his observations. During his former ascent, he saw the fleecy clouds spread out below him, while the canopy of heaven seemed of the deepest azure, more intense than Prussian blue. This time, however, he perceived no clouds gathered near the surface, but remarked a range of them stretching at a very considerable height over his head: the atmosphere, too, wanted transparency, and had a dull, misty appearance. The different aspect of the sky was probably owing to the direction of the wind, which blew from the north-north-west, in his first voyage, but in his second from the south-east.

While occupied with experiments at this enormous elevation, he began, though warmly clad, to suffer from excessive cold, and his hands, by continued exposure, grew benumbed. He felt, likewise, a difficulty of breathing, and his pulse and respiration were much quickened. His throat became so parched from inhaling the dry attenuated air, that he could hardly swallow a morsel of bread; but he experienced no other direct inconvenience from his situation. He had indeed been affected through the whole of the day with a slight headache, brought on by the preceding fatigues and want of sleep; but though it continued without abatement, it was not increased by his ascent.

The balloon was now completely distended, and not more than 33 lbs. of ballast remained; it began

Fig. 12. THE NASSAU BALLOON PASSING OVER LIEGE BY NIGHT. (*See page* 19.)

to droop, and M. Gay-Lussac, therefore, only sought to regulate its descent. It subsided very gently, at the rate of about a mile in 8 minutes; and after the lapse of 34 minutes, or at three-quarters past 3 o'clock, the anchor touched the ground, and instantly secured the car. The voyager alighted with great ease near the hamlet of St. Gourgon, about 16 miles north-west from Rouen. The inhabitants flocked around him, offering him assistance, and eager to gratify their curiosity.

As soon as he reached Paris, he hastened to the laboratory of the Polytechnic School with his flasks containing air of the higher regions, and proceeded to analyse it in the presence of Thenard and Gresset. Opened under water the liquid rushed into them, and apparently half filled their capacity. The transported air was found, by a very delicate analysis, to contain exactly the same proportions as that collected near the surface of the earth, every 1,000 parts holding 215 of oxygen. From concurring observations, therefore, it may be concluded that the proportions of oxygen and nitrogen in the atmosphere are essentially the same in all situations.

Sir John Leslie remarks truly, that the ascents performed by MM. Biot and Gay-Lussac are memorable, for being the first ever undertaken solely for objects of science. It is impossible, he says, not to admire the intrepid coolness with which they conducted these experiments, operating while they floated in the highest regions of the atmosphere, with the same composure and precision as if they had been quietly seated in their cabinets at Paris. Since that

time numerous ascents have been performed in different countries, generally by adventurers guided by no philosophical views, nor leading to any valuable results. We may, however, remark that in 1806, Carlo Brioschi, astronomer royal at Naples, made a balloon ascent in company with Andreani, the first Italian aëronaut. In attempting to rise to a greater height than Gay-Lussac had done, they got into an atmosphere so rare that the balloon burst from the great expansion of the gas. Its shreds served to check the velocity of their descent, and falling into an open space their lives were saved, but Brioschi contracted a disease which afflicted him till his death in 1833.

We must also notice the voyage performed by Messrs. Holland, Mason, and Green, in the year 1836, as being the longest on record, the distance of about 500 miles having been performed in 18 hours. The balloon was one which had been built by the proprietors of Vauxhall Gardens. It was pear-shaped, and when inflated was 60 feet high, and about 50 feet in its largest diameter. It required 85,000 cubic feet of gas fully to distend it, and its ascensive force was about 3,000 lbs. after allowing for the weight of the machine itself and its accessories, which were estimated at 1,000lbs. The car was of wicker-work, oval in shape, 9 feet by 4 feet. The aëronauts proposed to embark in this balloon, and to proceed on whatever course the winds might direct. They do not state how long they intended to remain in the air, but they took a fortnight's provisions, laid in a ton of ballast in bags, registered and marked, while all round the hoop, and in and about the car, were suspended cloaks, carpet bags, barrels of wood and of copper to provide for their safety in case the balloon should descend into the sea, speaking trumpets, barometers, telescopes, lamps, wine jars, spirit flasks, and other articles. They also had a machine for warming coffee and other liquids by means of the heat developed in the process of slaking lime. This was intended to supersede the necessity of making a fire. They had, however, a lamp, the flame of which was properly protected, to be burnt at night.

In addition to the ballast, the balloon was also furnished with a *guide-rope* about 1,000 feet long, to be lowered from the car by means of a windlass, and passing through a pulley attached to the hoop above, thus to remain freely suspended in the air. The use of this guide-rope is thus stated:—As soon as any alteration takes place, whereby the specific gravity of the balloon is increased, causing it to descend, the lower portion of this rope becomes gradually deposited on the ground, and acting like a discharge of ballast keeps constantly abstracting from her weight until her further descent is eventually checked, and she either continues to advance at the level at which she is thus reduced, or should her buoyancy from any cause be increased, she slowly rises and takes up the additional weight of rope which had been deposited on the ground. Another advantage of the guide-rope is, that in sailing by night the rope in trailing on the ground would give information to the aëronauts when the balloon was near the surface, and thus enable them to adjust the balloon to the required elevation by throwing out small portions of ballast.

Everything being got ready by 1.30 P.M. on the 7th November, 1836, the balloon rose slowly, and under the influence of a moderate breeze was borne away towards the south-east. At 2.48 they crossed the Medway, and at 4.15 saw the sea under the last rays of the setting sun. The cold caused the balloon to contract, and they descended into a current which bore them northward. As one of the objects of the expedition was if possible to get to Paris, they threw out ballast, and thus gained a higher level. In a few minutes they came over Dover, and at 4.48 quitted the shores of England, and in an hour were hovering over the French coast. As night advanced the scene was very striking. "The whole plane of the earth's surface for many a league around, as far and farther than the eye could distinctly embrace, seemed absolutely teeming with the scattered fires of a watchful population, and exhibited a starry spectacle below, that almost rivalled in brilliancy the remoter lustre of the concave firmament above. Incessantly during the earlier portion of the night, ere the inhabitants had retired to rest, large sources of light, signifying the presence of some more extensive community, would appear just looming above the distant horizon in the direction in which we were advancing, bearing at first no faint resemblance to the effect produced by some vast conflagration, when seen from such a distance as to preclude the minute investigation of its details. By degrees, as we drew nigh, this confused mass of illumination would appear to increase in intensity, extending itself over a larger portion of the earth, and assuming a more distinct form, and a more imposing appearance, until at length, having attained a position from whence we could more immediately direct our view, it would gradually resolve itself into its parts, and shooting out into streets, or spreading into squares, present us with the most perfect model of a town, diminished only in size, according to the elevation from which we happened at the time to observe it." In the course of the night, one of these scenes was particularly striking. "Situated in the centre of a district which actually appeared to blaze with the innumerable fires wherewith it was studded in every direction, to the full extent of all our visible horizon, it seemed to offer in itself, and at one glance, an epitome of all those charms which we had previously been observing in detail. The perfect correctness with which every line of street was marked out by its particular line of fires; the forms and positions of the more important features of the city, the theatres, and squares, the markets, and public buildings, indicated by the presence of the larger and more irregular accumulation of lights, added to the faint murmur of a busy population still actively engaged in the pursuits of pleasure or business, altogether combined to form a picture, which for singularity and effect certainly

could never have been conceived. This was the city of Liége, remarkable for the extensive iron works which, abounding in its neighbourhood, occasioned the peculiar appearance." (Fig. 12, page 17.) After leaving this fiery district the darkness gradually increased in intensity; it seemed to the aëronauts as if they were cleaving their way through an interminable mass of black marble in which they were imbedded, and which, solid a few inches before them, seemed to soften as they approached in order to admit them still farther within its cold and dusky enclosure. In this way they proceeded blindly, as it may well be called, until about 3.30 A.M. when in the midst of impenetrable darkness and profound stillness, an unusual explosion issued from the machine above, followed by a violent rustling of the silk, and all the signs which might be supposed to accompany the bursting of the balloon. The car was violently shaken; a second and a third explosion followed in quick succession; the danger seemed immediate, when suddenly the balloon recovered her usual form and stillness. These alarming symptoms seem to have been produced by the collapsing of the balloon under the diminished temperature of the upper regions after sunset, and the silk forming into folds under the netting. Now, when the guide-rope informed the voyagers that the balloon was too near the earth, ballast was thrown out, and the balloon rising rapidly into a thinner air experienced a diminution of pressure, so that its gaseous contents would expand, and in doing so open the folds of the collapsed silk, and produce this snapping noise which had occasioned so much alarm.

The cold during the night ranged from a few degrees below, to the freezing point. As morning advanced the rushing of waters was heard, and so little were the aëronauts aware of the course which they had been pursuing during the night, that they supposed themselves to have been thrown back upon the shores of the German Ocean, or about to enter the Baltic, whereas they were actually over the Rhine, not far from Coblenz. At 5.10 A. M. they gained their greatest elevation, which was about 12,000 feet, from which objects were seen at a distance of 150 miles on every side. The view of this stupendous landscape was enjoyed for about an hour, and at 6.15 they had the satisfaction of seeing the sun rise, which still more enhanced the beauties of the scene. Shortly afterwards the balloon descended rapidly to a lower level, and all again was dark, and it was not until they had seen the sun set twice, and rise three times, that daylight was fairly established. Even then, they were not aware of their locality, and actually supposed themselves to be hovering over the "boundless plains of Poland, or the barren and inhospitable Steppes of Russia." As soon as the mist had cleared away they hastened to descend, and after many difficulties succeeded in doing so, and found themselves "in the Duchy of Nassau, about two leagues from the town of Weilburg!" This is certainly a very complete answer to those who still advocate the possibility of guiding balloons, when in this, the grandest experiment in aërostation in modern times, the aëronauts were so completely at the mercy of the winds as not to know either the direction they had taken or the locality in which they had descended. Did they neglect to carry a compass with them?[1]

In this voyage all the resources of the aërostatic art were put into practice, and it will be seen how very small an advance has been made in it from the time when the first hydrogen gas balloon was launched into the air in 1783. The grandest improvement was in the use of coal-gas instead of the hydrogen, as previously obtained by a slow and costly process, an improvement which was first put in practice by Mr. Green, in his ascent from St. James's Park in 1820, at the coronation of George IV. The general introduction of coal-gas about this period, thus afforded a ready means for filling these aërial toys, which was speedily taken advantage of wherever gas-works were at hand. Coal-gas is between four and five times heavier than its own bulk of hydrogen, so that it would require about four or five times the quantity to produce the same effect; but this supposes the hydrogen to have been pure, which it never was; for not only was it loaded with moisture, but it quickly became contaminated with air; so that the balance in favour of pure hydrogen, without reference to its increased cost, cannot be very great. The specific gravity of the coal-gas of London is about 0.4, atmospheric air being 1.0; so that after allowing for the weight of the balloon, the car, the voyagers, the ballast, &c., there is still a sufficient amount of ascensional force to convey the machine and its freight into the upper regions. The ballast generally consists of bags of sand, which, on being shaken out, relieve the balloon of a portion of its load, and thereby increase the ascensional force. But as the balloon ascends, the atmospheric pressure diminishes, and causes the gas to expand, and it would in fact burst the envelope unless means were taken to allow a portion to escape. This is done by means of a safety-valve placed at the top of the balloon, and regulated by a cord passing down into the car. By this means, also, the aëronaut regulates his descent; for as the gas is allowed to escape, the weight of the machine gradually destroys the ascensional force, and the balloon descends. He still retains sufficient buoyancy to prevent the balloon from falling with a jerk, and when near the earth, a grappling-hook attached to one extremity of a rope is thrown out; when this has taken hold of the earth, the balloon is landed by drawing the rope in, and then all the remaining gas is allowed to escape.

Thus it will be seen that the only guiding power possessed by the aëronaut is that of ascent and descent within certain limits. By throwing out ballast he can ascend; by letting out gas he can descend.

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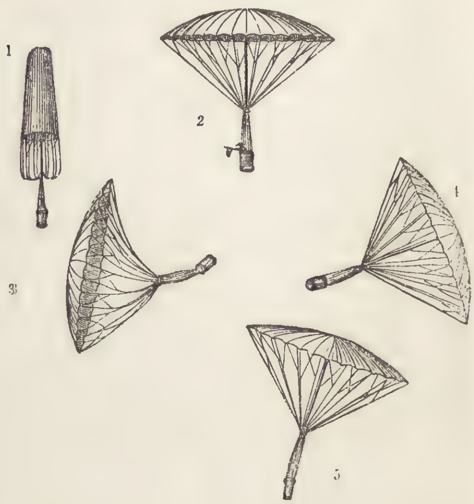
(1) The details of this voyage, and a variety of particulars and speculations respecting balloons, are given by Mr. Monck Mason, in his very amusing work entitled "Aëronautica, or Sketches Illustrative of the Theory and Practice of Aërostation." London, 1838.

He is absolutely powerless in guiding the balloon horizontally; for there is no analogy between a balloon and a ship sailing in the water. In the ship the action of the water on the rudder is a guide to the impelling force of the winds acting on the sails. No such regulator as the rudder can be applied to a balloon, because it is sustained in, as well as impelled by the air. It is stated, however, by Mr. Green, and Mr. Monck Mason, from their own aëronautic experience, that "in this country, whatever may be the direction of the wind below, within 10,000 feet above the surface of the earth, the direction of the wind is invariably from some point between the north and west." If this really be the case, the aëronaut has only to ascend to the height named, and he will find an upper current always ready to convey him in any direction between south and east.

One of the chief dangers in aërial excursions arises from a rapid and premature descent. To guard, in some degree, against such an occurrence, the *parachute*, or guard for falling, was introduced. The parachute resembles a large umbrella, sufficiently strong to resist the action of a moderate wind, and sufficiently large to offer a resistance equal to the weight of the person descending in it, so that it may reach the earth with a velocity not exceeding that of the shock which a person can sustain without danger.

Blanchard was the first aëronaut who attached a parachute to a balloon. During the excursion which he undertook from Lisle, in August, 1785, when he traversed a distance of 300 miles without halting, he let down a dog from a vast height in the basket of a parachute, and the poor animal, falling gently through the air, reached the ground unhurt. Another aëronaut, M. Garnerin, even ventured on many occasions to descend from the clouds in this frail machine. During the short peace of 1802, he visited London, and made two ascents with his balloon, in the second of which he threw himself from an amazing elevation with a parachute. This consisted of 32 gores of white canvass formed into a hemispherical case of 23 feet diameter, at the top of which was a round piece of wood with a hole in its centre, admitting short pieces of tape to fasten it to the several gores of the canvass. About $4\frac{1}{2}$ feet below the top, a wooden hoop 8 feet in diameter, was attached by a string from each seam, so that when the balloon rose the parachute hung like a curtain from this hoop, as in No. 1 of Fig. 13. Below was suspended a cylindrical basket covered with canvass, about 4 feet high and $2\frac{1}{4}$ feet wide. In this basket the aëronaut, dressed in a close jacket, placed himself and ascended from an inclosure near North Audley Street, at 6 P.M. of the 2d September. After hovering 7 or 8 minutes in the upper region of the atmosphere, he cut the cord by which his parachute was attached to the net of the balloon. The balloon immediately ascended and was lost, but the parachute instantly expanded, as in No. 2, and for some seconds descended with an accelerating velocity, until it became tossed extremely, as in Nos. 4 and 5, and took such wide oscillations that the basket was sometimes thrown into a nearly horizontal position, as in No. 3. At the same time being carried along by the wind, the parachute passed over Marylebone and Somers Town, and almost grazed the houses of St. Pancras.

Fig. 13.



At length it struck the ground in a neighbouring field, but with a shock so violent, that Garnerin was thrown on his face and injured. It appears that one of the stays of the parachute had given way and had thrown the apparatus out of its proper balance, thus threatening the aëronaut with destruction during the whole of his descent.

Mr. Monck Mason states an interesting meteorological fact as having been established by aëronautic observation. It appears that whenever a fall of rain occurs, and the sky is at the same time entirely overcast with clouds, there will be found to exist another stratum of clouds at a certain elevation above the former. So also, when the sky is entirely overcast, and rain is altogether or generally absent, the aëronaut, upon traversing the canopy immediately above him, is sure to enter upon another hemisphere, either perfectly cloudless or nearly so. Mr. M. Mason states that this fact has been verified during many hundred ascents. For example, during an ascent on the 12th October, 1837, "the sky was completely overspread with clouds, and torrents of rain fell incessantly during the whole of the day. Upon quitting the earth, the balloon was almost immediately enveloped in the clouds, through which it continued to work its way upwards for a few seconds. Upon emerging at the other side of this dense canopy, a vacant space, of some thousand feet in breadth, intervened, above which lay another stratum of a similar form and observing a similar character. As the rain, however, still continued to pour from this second layer of clouds, to preserve the correctness of the observation a third layer should by right have existed at a still further elevation; which, accordingly, proved to be the case. On the subsequent occasion of the ascent of the same balloon, (October 17th,) an exactly similar condition

of the atmosphere, with respect to clouds, prevailed; unaccompanied, however, with the slightest appearance of rain. No sooner had the balloon passed the layer of clouds immediately above the surface of the earth, than, as was anticipated, not a single cloud was to be found in the firmament beyond; an unbroken expanse of clear blue sky every where embracing the frothy plain that completely intercepted all view of the world beneath."

The following particulars are abridged from Mr. Mason's work. When the balloon is held down to the earth, there are many effects which remind the aëronaut of the presence of the ocean of air into which he is about to be launched: the balloon heaves, the silk flaps and rustles, and the wind sighs through the cordage; but the moment he quits the earth not a motion is felt, not a breath of wind is perceptible; the balloon, as if arrested by some powerful and invisible agent, suddenly assumes an upright posture, and stands, as it were, fixed, rigid, and immovable; and the mind of the adventurer becomes impressed with the idea of an universal and unnatural calm. This state of things continues so long as the balloon is left free to pursue her own course upon the same level. Totally independent of the rate or direction of the current, the idea of absolute quiet remains the same, whether the actual progress of the balloon be 1 or 100 miles an hour, whether it be in one continued line, or subject to the most rapid and incessant variation. The greatest storm that ever racked the face of nature is, in respect to its influence upon this condition of the balloon, as utterly powerless as the most unruffled calm. To such an extent is this the case, so truly indeed is atmospheric resistance a nullity to the aëronaut, that were we to suppose him (by way of illustration) suddenly transported to the West Indies, the birthplace and habitation of the tornado and the hurricane, traversing the skies at a time when one of the wildest and fiercest was executing its utmost powers of devastation, looking down from his airborne car, and beholding houses levelled, trees uprooted, rocks translated from their stony bed and hurled into the sea, earth and ocean in mutual aggression, encroaching upon each other's limits, and all the various signs of desolation by which its path is marked, he might nevertheless hold in his hand a lighted taper without extinguishing the flame, or even indicating by its inclination to one side or the other, the direction of the mighty agent by which such awful ravages had been created.

AFFINITY. Chemical affinity or attraction, is that particular power or force by which dissimilar bodies become combined in intimate relationship,[1] (Latin *affinis*, a kinsman,) forming a new substance, whose properties are, for the most part, entirely different from those of its component parts. If two bodies be simply mixed together, the properties of the mixture form a *mean* between those of its components; but if two bodies combine chemically, we get different properties. In the mixture we may still recognise the distinctive properties of the two bodies brought together; in the chemical compound we have the properties of a third substance. For example, a mixture of magnesia and water produces almost no chemical change; the combination is almost purely mechanical; the water dissolves less than a six-thousandth part of this earth, so that by passing the mixture through a filter, the water and the magnesia can be almost perfectly separated. If, however, we add magnesia to dilute sulphuric acid, a true chemical combination takes place: 20 parts of magnesia combine with 40 of sulphuric acid and 63 of water to form 123 parts of sulphate of magnesia, a crystalline salt, soluble in its own weight of water at 60°, and of a nauseous bitter taste. In fact, we get a new compound, whose chemical properties are totally different from those of its component parts. The acid is intensely sour and caustic, the earth is insipid and slightly alkaline; combine the two and we get Epsom Salts.

To take another example; the atmospheric air is composed essentially of two gases, oxygen and nitrogen, which are mechanically mixed in the proportion of 4 volumes of nitrogen to 1 of oxygen. If these bodies be combined chemically and in different proportions, we get totally new substances; 14 parts, by weight, of nitrogen combined with 8 parts, by weight, of oxygen, produces a gas called *nitrous oxide*, which has a faint, agreeable smell; is absorbed by cold water to the extent of about three-fourths of its volume; mixed with hydrogen and ignited, it explodes; combustible bodies burn in it with increased brilliancy, and when taken into the lungs it produces a sort of intoxication, generally accompanied by convulsions of laughter. 14 parts of nitrogen with 16 of oxygen produce a gas, the *nitric oxide*, which has totally different chemical properties. Cold water scarcely absorbs it; mixed with hydrogen it burns with a green flame; a lighted taper will not burn in it; any attempt to breathe it produces suffocation, and when let out into the air it forms a vapour of a reddish brown colour. 14 parts of nitrogen combined with 40 of oxygen form nitric acid, a corrosive poison, and one of the most powerful of the mineral acids.

But it is not always easy to mark the limit between mechanical mixture and chemical combination. When a body dissolves in a liquid, there is a weak kind of affinity between the substance dissolved and the solvent, as when salt is dissolved in water; but this can scarcely be called a case of affinity, for by evaporating the solution the salt can be recovered unchanged, which cannot be done when bodies combine chemically.

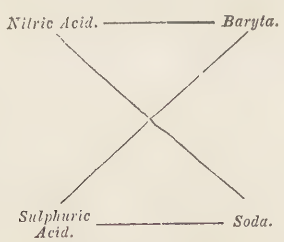
Chemical affinity, as already stated, applies only to the union of dissimilar bodies. There are some bodies, such as oil and water, water and mercury, which refuse to unite, and in such case it is said that there is no affinity between such bodies. This is not telling us much, for as the real nature of affinity is not known, we only disguise our ignorance by stating

(1) The term affinity was first employed by Boerhaave in a figurative sense, to indicate certain peculiar attachments and aversions between different bodies.

that oil and water will not unite *because* these bodies have no affinity for each other.

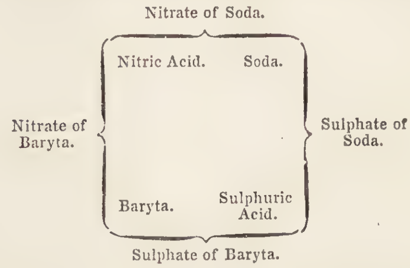
Chemists distinguish various kinds of affinity. *Single affinity* is that in which two bodies unite to form a binary compound. These may be two simple substances, as when oxygen and iron unite to form oxide of iron, or sulphur and copper to form sulphuret of copper; or two compounds may unite, as sulphuric acid and oxide of iron, to form sulphate of iron. But a simple substance does not often unite with a compound one; thus sulphuric acid does not unite with iron, nor does sulphur unite with oxide of copper. If we oxidise the iron, the acid unites with it readily; and if we deoxidise the copper, the sulphur will unite with it. There are, however, exceptions to this rule.

Affinity is also spoken of as being *elective.* Thus if dilute nitric acid be poured upon a mixture of lime and magnesia, the acid will unite with the lime in preference to the magnesia. Hence it is said, that nitric acid has a greater affinity for lime than for magnesia, and the fact may be shown in another way. If lime water be added to a solution of nitrate of magnesia, nitrate of lime is formed and magnesia is thrown down as an insoluble precipitate. This is a case of *single elective affinity.* There is another mode by which compounds are formed, namely, by *double decomposition* or *double elective affinity.* This is very useful in obtaining compounds which could not otherwise be procured, in many cases, without great difficulty. For example, nitrate of baryta and sulphate of soda are salts soluble in water. If the solutions of these salts be mingled together, two new compounds are formed, one of which is soluble and the other not. The change that takes place will be understood from the following diagram, in which the



substances before being mixed are shown in the parallel lines, and after mixture in the diagonal lines. The nitric acid quits the baryta to unite with the soda, forming nitrate of soda, which remains in solution; and the sulphuric acid quits the soda to unite with the baryta, forming sulphate of baryta, which is an insoluble precipitate. Some of the processes of the dyer depend upon such a case as this, which may be still more completely illustrated by the following diagram, where the solutions before being mixed are placed on the outside of the perpendicular lines, their component parts are shown within them, and the new compounds are stated on the outside of the horizontal lines.

It was formerly supposed that the relations of affinity were fixed and constant between the same substances, and the older chemists took great pains to prepare tables of what was called the *precedence*



of affinities. The following is an example of one of these tables, which illustrates the relative affinities of a number of bases for sulphuric acid, each decomposing the combination of the acid with the base below it. Thus magnesia decomposes sulphate of ammonia; lime displaces the acid from sulphate of magnesia, &c. The salts are supposed to be dissolved in water.

SULPHURIC ACID.

Baryta.
Strontia
Potash.
Soda.
Lime.
Magnesia.
Ammonia.

Professor Fownes remarks, that "the order pointed out in these lists, is now acknowledged to represent the order of precedence *for the circumstances* under which the experiments were made, but nothing more. So soon as these circumstances become changed, the order is disturbed. The ultimate effect, indeed, is not the result of the exercise of one single force, but rather the joint effect of a number, so complicated and so variable in intensity, that it is seldom possible to predict the consequences of any yet untried experiment."[1]

There is an extensive class of chemical actions which have been grouped together under the general title of *disposing* affinity. A familiar example of this occurs in the preparation of hydrogen gas from zinc or iron and dilute sulphuric acid. A piece of polished zinc or iron remains perfectly bright under water for any length of time, and does not show any tendency to decompose it. But if a small quantity of sulphuric acid be added, the water begins to be decomposed, hydrogen is freely evolved, a film of oxide forms on the metal, and this is dissolved by the acid as fast as it is formed. This appears to be the use of the acid in this experiment, but it is difficult to explain why the oxide should be produced when the acid is present and not otherwise.

Chemical affinity is promoted by many circumstances, especially by diminishing the cohesive attraction of the bodies to be acted on. Thus a lump of marble in dilute hydrochloric acid slowly wastes away, but by reducing the marble to powder, the action is very

(1) Fownes' Manual of Chemistry, 1848

rapid and energetic. A lump of antimony thrown into chlorine gas is scarcely acted on, but the metal in the state of powder immediately combines with the gas, with the evolution of heat and light, and a chloride of antimony is at once formed. Masses of iron, copper, and lead, resist the action of the atmosphere; they become slightly tarnished with oxides which protect them from further action; but in a state of minute division they are acted upon with great energy, and often present the phenomena of combustion by simple exposure to the air. It is also often necessary for the exhibition of chemical affinity, that one of the bodies should be in a fluid state. Solutions mostly depend on this condition; and here again a state of minute division is important, merely by increasing the surface of contact between the solvent and the body to be dissolved, thus offering an immense number of points where the action may simultaneously be exerted.

Many bodies will only combine in what is called the *nascent state*, or at the moment of separation from combination. Thus carbon and nitrogen will not combine with gaseous hydrogen; but when these bodies are simultaneously liberated from some previous combination they unite readily, as when organic matters are destroyed by heat or by putrefactive fermentation.

Affinity is in most cases greatly promoted by heat. Melted sulphur will not combine with carbon, but by raising the sulphur to the state of vapour, and bringing it in contact with red-hot charcoal, these bodies combine and form sulphuret of carbon, a limpid, colourless liquid. Charcoal requires to be made red-hot before it will burn in oxygen gas, that is, before it will combine with oxygen. At ordinary temperatures, oxygen may be mixed with hydrogen and other inflammable gases without combining with them, but on the approach of flame or the electric spark, combination takes place immediately. Cold water dissolves many salts only to a limited extent, but the application of heat greatly increases the solvent power of the water. There are, however, some salts which dissolve more freely in cold than in hot water, but these form exceptions to the general rule. Heat also favours decomposition as well as affinity. For example, if mercury be heated in contact with the atmosphere, it is converted into a peroxide by combining with the oxygen of the air; now if this compound be again heated to a higher temperature than was required for its formation, it is decomposed; oxygen is given off, and the mercury returns to the metallic state. So also, if iron filings be heated to redness in a porcelain tube, and vapour of water be passed over them, the water is decomposed, its oxygen combining with the iron to form an oxide, and its hydrogen escaping from the extremity of the tube. If, on the contrary, oxide of iron be heated in a tube and a stream of dry hydrogen be passed over it, the metal is immediately reduced by the hydrogen uniting with the oxygen of the oxide, and forming water, which escapes as a jet of steam from the extremity of the tube. "In these experiments," says Fownes, "the affinities between the iron and oxygen and the hydrogen and oxygen are so nearly balanced, that the difference of *atmosphere* is sufficient to settle the point. An atmosphere of steam offers little resistance to the escape of hydrogen; one of hydrogen bears the same relation to steam; and this apparently trifling difference of circumstances is quite enough for the purpose."

Electricity has considerable influence over chemical affinity. A mixture of oxygen and hydrogen instantly combines by passing an electric spark through it, but this is probably a mere effect of heat. By passing a series of electric sparks through a mixture of oxygen and nitrogen, nitric acid is formed. A portion of this acid also appears to be formed in the atmosphere during a thunder storm, and the action of electricity in these cases is probably more specific than that of heat. But of all the various states of electricity, galvanism is the most interesting in a chemical point of view. By means of the voltaic pile or battery, a large number of chemical compounds have been decomposed. When, for example, two platina wires are connected with the poles or electrodes of a voltaic battery, and their unconnected ends are immersed in water, oxygen gas is evolved at the positive pole, or, as it is now called, the *anode*,[1] and hydrogen gas is evolved at the negative pole or *cathode*.[2] So, also, when saline solutions are submitted to the action of the battery, acids are developed at the anode, and alkaline bases at the cathode.

Now it is a law of electricity, that bodies dissimilarly electrified attract each other; and as in these decompositions oxygen, chlorine, acids, &c. invariably go over to the positive pole, and hydrogen, the metals, inflammable substances in general, and the alkalies, appear at the negative pole, it has been supposed that chemical affinity, or that force with which bodies combine, is a consequence of their being in opposite electrical states; that an acid being negative, and an alkali being positive, unite to form a salt, and that when the union is once effected, the electricity of the compound exists in a neutral state, or in a state of equilibrium. When, however, the superior force of the voltaic battery is brought to bear upon such a compound, its constituents separate and return to the original electric state which they had before combination. Hence it has been supposed, that when substances or their atoms are similarly electrified, they refuse to combine, but that they may be made to do so by communicating to them opposite electrical states. This theory has been useful to chemistry, but it is by no means certain that chemical affinity is identical with electrical attraction. According to Dr. Faraday, chemical affinity is merely a result of the electrical state of the particles of matter. He has found that when bodies are combined or decomposed by an electric current, the composition and the decomposition are always effected according to the laws of definite proportions; and

(1) That is, the surface at which the electric current enters the electrolyte.

(2) The surface at which the electric current leaves the body under decomposition

that the quantity of electricity requisite for the decomposition of a substance, is exactly the quantity necessary for its composition. Thus the quantity of electricity which can decompose a grain of water is exactly equal to the quantity of electricity which unites the elements of that grain of water together. [ATOMIC THEORY.]

Light has also considerable influence in controlling chemical affinity. Hydrogen and chlorine gases mixed and exposed to the sun's rays combine with explosion, and form hydrochloric acid. Chlorine and carbonic oxide gases exert no action on each other until they are exposed to the light, when they combine and form phosgene gas. The beautiful chemical arts of PHOTOGRAPHY and DAGUERREOTYPE depend upon the action of light upon chemical substances.

AGATE, from ἀχάτης, a stone, said by Theophrastus to come from the river Achates, in Sicily, now called the Drillo, in the Val di Noto. It is one of the numerous forms in which silica is arranged, and contains 98 per cent. of that mineral. It is not transparent, like rock-crystal, but almost opaque, with a resinous or waxy fracture, and with various shades of colour produced by the presence of minute portions of iron. When agates are cut open they display a singular variety of forms, in some cases resembling animals and plants, in others zigzag lines like the plan of a modern fortification, and hence this variety is called *Fortification Agate.* These lines are the edges of successive layers or deposits of the mineral during the process of its formation. As the internal surfaces are capable of receiving a high degree of polish, agates are much valued as ornamental stones. They are extensively used at Paris and elsewhere, in the manufacture of cups, rings, seals, handles for knives and forks, sword-hilts, beads, smelling-bottles, snuff-boxes, and other articles. Burnishers are also formed of agate, for the use of the bookbinder and other mechanics. Agates are usually met with in that variety of trap-rocks called

Fig. 14. THE AGATE.

amygdaloid: they form in it detached rounded nodules, not cemented to the rock, but easily separable from it, having generally a thin layer of green earth interposed, and a rough, irregular exterior. Agates are also met with as loose pebbles in the beds of rivers or in gravel, and they vary in size, from that of a millet seed to a foot in diameter; but the most common size is 1, 2, or 3 inches in diameter. The colours of agate may be darkened by boiling the stone in oil, and then dropping it into sulphuric acid. A little oil is absorbed by some of the layers, and this becomes blackened or charred by the acid. Fig. 14 is a copy of a good specimen of an agate with chalcedony.

There are various other siliceous stones closely allied to agate, and not to be distinguished from it in chemical composition, except as respects the colouring matter of one or two of them. These are, 1. *Carnelian,* so called from the Latin *carnis,* flesh, some of the most common varieties being of a flesh colour. There are, however, various shades of red and yellow, but the deep, clear red is the rarest, and most valuable. The colours may be deepened by exposing the stones for several weeks to the sun's rays. The chief supply of carnelians is from Japan; they are also imported from Bombay, after being collected in the province of Guzzerat; but the best varieties are said to come from the gulf of Cambay. Many antique gems are in carnelian, and the stone is now much used for seals and beads. The Japanese cut beads of it into the form of the fruit of the olive. 2. *Calcedony,* so called from being found at Chalcedon, in Bithynia, opposite to Constantinople. This is a gem of a uniform milky white, or pale yellow colour: it often has a wavy structure, and a peculiar blistered surface. It is found abundantly in the Faroe Islands, in Iceland, Cornwall, and many other places. It sometimes occurs in large masses, of which cups and vessels are formed. 3. *Onyx.* In this variety of agate, the siliceous particles are arranged in alternate flat layers, of an opaque white and translucent grey or brown colour, resembling the marks on the human nail, whence its name from the Greek word ὄνυξ, a nail. Some of the most beautiful of the ancient cameos were executed in this material, the figure being cut out of the opaque white, while the dark parts formed the ground; or the white parts formed the ground, and the dark parts the figure. 4. *Sardonyx,* a variety of onyx from *Sardes,* in Lydia, or, as some say, from *Sardo,* the Greek name for Sardinia. In this stone, the opaque white alternates with a rich, deep orange brown, which, when considerably translucent, greatly adds to its value. 5. *Mocha stones* and *moss agates* are transparent varieties of calcedony, the section of which exhibits various forms produced by iron, manganese, bitumen, and chlorite or green earth, but sometimes, also, by the presence of real vegetable bodies, such as confervæ and mosses. Mocha stones are so called from having been brought from Mocha in Arabia. 6. *Blood-stone,* a green agate coloured by chlorite with numerous bright red spots like drops of blood. It is also called *Heliotrope,* and *Oriental Jasper.* 7. *Chrysoprase,* from χρύσεος, beautiful, and πράσον, a leek; a variety of calcedony found in Silesia; its colour, which is of an apple-green, is due to oxide of nickel. 8. *Plasma,* a green semi-transparent calcedony, of a dark tint sprinkled by yellow and whitish dots. It is coloured by chlorite.

The figured agates of commerce are chiefly obtained from Oberstein, a small town in the valley of the Nahe, not far from Mayence. The business of cutting and polishing the agates, occupies a considerable number of the inhabitants. The surface is first coarsely ground by large mill-stones of a hard, reddish sandstone, moved by water-wheels, in numerous small mills scattered along the stream. The polish is afterwards given on a wheel of soft wood, moistened and imbued with a fine powder of hard red tripoli, found in the neighbourhood. Agates are found in many parts of Scotland, especially at the Hill of Kinnoul, near Perth; they are hence called *Scotch pebbles.*

In the mineralogical collection of the British Museum (Room IV.), is a specimen of Globular or Egyptian Jasper, which exhibits in the two fractural surfaces a likeness of the poet Chaucer. Fig. 15 is an accurate copy of this curious specimen. In the same case [No. 24] are other specimens of siliceous minerals, the lines of which fall into the shapes of animals, &c.

Fig. 15.

AIR, (from the Greek and Latin *aer,*) a term now limited to the atmosphere, although formerly applied to various gases; thus oxygen was called *vital air;* hydrogen, *inflammable air;* carbonic acid, *fixed air;* ammoniacal gas, *alkaline air,* &c. The atmosphere or sphere of gases (ἀτμοί) is the general term applied to the whole gaseous portion of this earth. Being much lighter than either land or water, it floats or rests upon them, and rises to the height of probably 40 or 50 miles above the sea-level. It consists essentially of two gases, OXYGEN and NITROGEN, in a state of mechanical mixture. One hundred parts by weight, contain 77 parts nitrogen and 23 parts oxygen; or by measure, 79.19 nitrogen, and 20.81 oxygen. So that if we mix 1 volume of oxygen with 4 volumes of nitrogen, we get a mechanical compound almost identical with pure atmospheric air. Oxygen is remarkable for its active properties: it promotes combustion, respiration, and other chemical changes, with great energy. Nitrogen, on the contrary, is inert; it supports neither respiration nor combustion, and its chief use in the atmosphere seems to be to dilute the oxygen. During the processes of respiration and combustion, a quantity of carbon is set free, every 6 parts of which, by weight, unite with 16 parts by weight of oxygen, and form a compound gas, called CARBONIC ACID, which is always present in the atmosphere in small but varying quantities. In 10,000 volumes of atmospheric air, the mean proportion of carbonic acid is only 5 volumes, and this varies from 6.2 as a maximum, to 3.7 as a minimum. Near the surface of the earth, the proportion of carbonic acid is greater in summer than in winter, and during night than during day. It is also rather more abundant in elevated situations, as on the summits of high mountains, than in the plains; and, although this gas is considerably heavier than its own bulk of pure atmospheric air, (its specific gravity being about 1.52, air being 1,) yet it appears to be diffused through the whole mass.

By the evaporation of the waters of the earth, and of moist surfaces, the atmosphere is constantly supplied with a quantity of aqueous vapour. In 100 parts by weight of atmospheric air, the mean quantity of watery vapour is nearly one part and a half. The amount, however, varies with the temperature. At 50°, the mean temperature of England, the air contains $\frac{1}{120}$th of its weight of water in an invisible state without forming cloud, mist or rain. If it contain more than this, it is precipitated in a visible form. At a higher temperature a larger quantity of vapour may remain invisible; thus, at 82°, the mean temperature of the equator, the air may contain as much as $\frac{1}{43}$d of its weight of invisible steam; and air that contained only $\frac{1}{125}$th would be injuriously dry, though the same air cooled down to 50°, would be at its maximum of humidity. (HYGROMETER.)

As the sea contains a little of everything that is soluble in water, so the atmosphere contains a little of everything capable of existing in the gaseous form at common temperatures. Ammonia is always present, and is supposed to be the source of nitrogen in plants; while in crowded cities, and in the neighbourhood of gas works, smelting furnaces, sewers, stagnant pools, sulphur-springs, &c. there is much local contamination of the air from the presence of different gases. Various forms of infection, malaria, and marsh-miasma, probably arise from the presence of noxious gases in the air. Berzelius states that in the first experiments which he made upon seleniuretted hydrogen, he let up into his nostrils a bubble about the size of a pea. "It deprived me so completely of the sense of smell, that I could apply a bottle of concentrated ammonia to my nose without perceiving any odour. After 5 or 6 hours I began to recover the sense of smell, but a severe catarrh remained for about 15 days." On another occasion a little of the gas accidentally escaped; it produced a sharp sensation in the nose, red eyes, and a dry and painful cough, which at length was succeeded by expectoration, tasting like the vapour from a boiling solution of corrosive sublimate. "These symptoms were removed by a blister to my chest. The quantity of seleniuretted hydrogen gas, which on each of these occasions entered into my organs of respiration, was much smaller than would have been required of any other inorganic substance whatever to produce similar effects." Dr. Prout quotes these facts to show how small a quantity of accidental ingredients diffused in the atmosphere may produce powerful effects in the human system, and may even be the origin of influenza, and other epidemic disorders.

With respect, however, to the two essential ingredients of the atmosphere, they always exist in the

same proportions, however the air may be vitiated by carbonic acid, animal effluvia, and other accidental ingredients. Air has been brought from the summits of Mont Blanc and Chimborazo, and from the plains of Egypt; it has been collected and examined in crowded cities, and in fever hospitals; but in all cases the proportions of oxygen and nitrogen remain unaltered, the diffusive energy of the gases maintaining this perfect uniformity of mixture.

This mechanical compound the atmosphere forms, therefore, a fluid ocean at the bottom of which we live, and which envelopes everything, and exerts such a pressure upon everything, as is quite incredible to persons who approach this subject for the first time.

Although air is invisible, and is very much lighter than solid and liquid bodies, yet like them it is material, and possesses many of their physical properties, together with other properties peculiar to aëriform fluids. Air possesses impenetrability; that is, it will not allow the entrance of another body into the space where it is present. If a vessel be completely full of water, a solid plunged into it will displace a portion of the water equal to the bulk of the solid. So, also, if we plunge a solid into what is called an empty glass, it will displace a portion of the air contained in such glass equal to its own bulk. The impenetrability of air is well illustrated by plunging an inverted goblet into a vessel of water, keeping the edge horizontal, and it will be found that to whatever depth we plunge it, the water will not entirely fill it. The air will be compressed into a smaller space, but will not be displaced. A diving bell at a depth of 34 feet below the surface of the water, will be half filled with water; at 100 feet it will be three-quarters filled; at 1,000 feet it will be filled to within a thirtieth; but on drawing it up to the surface the air will expand to its original bulk, and drive out all the water.

Air being material also possesses *weight;* that is, it obeys the attractive influence of the earth, and gravitates towards its centre. This may be proved by suspending a copper flask, of the capacity of 100 cubic inches, to one extremity of the arm of a delicate balance, and accurately counterpoising it with weights in the opposite scale. If the air be pumped out of the flask it will be found to have lost weight: it will have lost about 31 grains; but on readmitting the air the flask will weigh as much as before. It has been found by accurate experiments, that 100 cubic inches of pure and dry air, weigh 31.0117 grains, at the temperature of 60°, and under a pressure of 30 inches.

Air, then, is a ponderable substance, and, in common with all such, has *inertia,* that is, it cannot be set in motion without the communication of some force, and when in motion, it cannot be retarded or brought to rest without the opposition of force. Its inertia, like that of all other bodies, is exactly proportional to its weight; and as this is small compared with its bulk, a small force is sufficient to impart motion to a large bulk of air. It obeys the laws of motion common to ponderable bodies, and its *momentum,* or amount of force which it is capable of exerting upon bodies opposed to it, is estimated in the same way as for solids, viz. by multiplying its weight by its velocity. The momentum of air is usefully employed as a mechanical force in imparting motion to windmills and ships.

Another consequence of the weight of air is its *pressure.* We have seen that 100 cubic inches of air weigh about 31 grains. This however is only at or near the level of the sea, with the barometer standing at 30 inches; for if this 100 inches of air be taken up in a balloon, to the height of 14,282 feet, or 2.705 miles, the 100 cubic inches will expand to 200, because, at that elevation, we have ascended above half the atmosphere, and the 100 cubic inches of air has to bear only half the pressure to which it was subjected at the level of the sea. Now it is a law peculiar to gaseous matter, that its density is proportional to the pressure that confines it; that is to say, by doubling this pressure we compress any air or gas into half its former bulk; and on the contrary, by removing half the pressure from any air or gas, it expands to twice its ordinary bulk; so that there does not appear to be any limit to the space which any quantity of air, however small, would fill if relieved of all pressure. Thus, the zone or shell of air which surrounds the earth, to the height of nearly 2¾ miles from its surface, contains one half of the atmosphere; and the remaining half being relieved of this superincumbent pressure, expands into another zone or belt, of the thickness of 41 or 42 miles.

The pressure of the air at the sea level, will be further examined when we come to notice the BAROMETER; but its amount may be shown by the Magdeburg hemispheres, fig. 16, which consist of 2 hollow hemispheres of brass, which fit together with smooth edges. The lower hemisphere is furnished with a short tube opening into it, which can be opened or closed by means of a stop-cock. On screwing this tube into the table of an air-pump and placing the two hemispheres together, the air can be withdrawn from the hollow sphere thus formed, and on turning the stop-cock and removing the apparatus the air cannot re-enter. A handle may be screwed to the short tube, and if two persons pull in opposite directions they will be unable to separate the hemispheres.

Fig. 16.

If the sphere be 6 inches in diameter, its section through the centre will be about 29 square inches, and supposing the vacuum to be perfect, a weight of 420lbs. will be required to separate the hemispheres.[1]

(1) This experiment derives its name from Magdeburg, the place where it was first invented by Otto Güricke, a wealthy magistrate, who, in the year 1654, had the honour of exhibiting it on a large scale, before the princes of the empire and the foreign

Now $\frac{420}{29}$ = about $14\frac{1}{2}$ lbs. which is the amount of atmospheric pressure upon 1 square inch of surface.

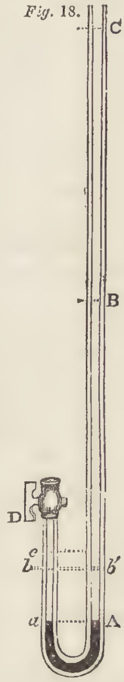
To this pressure all bodies animate and inanimate, situated at or near the level of the sea, are subject. By calculating the number of square inches on the surface of the body of a man of ordinary stature, and multiplying this number by $14\frac{1}{2}$, we get the number of pounds pressure to which his body is subject from the atmosphere: this will be found to amount to no less than 33,600 lbs., or about 15 tons. Why then is he not crushed beneath so enormous a load? is a very natural inquiry. To this it may be answered, that at the bottom of the ocean of water, many frail and delicate animals live and enjoy life, and move about with perfect freedom, just as we do at the bottom of our ocean of air; and yet these creatures are subject to a pressure of from 60 to 90 times greater than we sustain. They are not crushed because the hydrostatic pressure is equal on all sides; the bodies of these animals are equally pressed above, below, and around, and the fluids within the animal are also either of similar density or they are nearly incompressible. So, also, our atmosphere presses equally in all directions, and our bodies are filled with liquids capable of sustaining pressure, or with air of the same density as the external air, so that the external pressure is met and counteracted by the internal resistance. Fishes which live at great depths in the sea, are as effectually destroyed when drawn up to the surface and the hydrostatic pressure removed, as we should be if taken to a great height in the atmosphere, where the pneumatic pressure would be removed or nearly so. We become painfully sensible of atmospheric pressure in the operation of cupping, and also in the experiment with the hand-glass, fig. 17, which is a stout glass open at both ends: if the broader end be placed on the table of the air-pump and the upper end be closed with the palm of the hand, the removal of a portion of air from the interior of the glass will cause an intolerable load to be felt on the back of the hand: this is the atmospheric pressure now unbalanced, because it does not press below as well as above the hand.

Fig. 17.

It has been stated that when a given volume of air is released from pressure it will expand to an indefinite extent, and that when the same amount of pressure is restored it will regain its former bulk. This property of *elasticity* is one of the most striking features of aëriform matter, and is a consequence of its peculiar structure. The atoms or particles of solids are held together by an attractive force called *cohesion*, which differs in different solids, as is evident from the various degrees of force required to overcome it, as in breaking them, or crushing and grinding them to powder. In liquids, the cohesive attraction is so weak that the particles glide over each other and instantly mould themselves to the form of the vessel or channel necessary to contain them. In air, gases, and vapours, cohesive attraction is altogether absent; the particles not only do not cohere, but repel each other with so powerful a force, that they constantly tend to separate themselves from each other, so as to occupy a larger space. It is this repulsive force which constitutes the elasticity of gaseous bodies.

This property of air, and the law by which it is governed, can be illustrated by means of a long bent glass tube, open at its longer extremity, and furnished with a stop-cock at the shorter. The stop-cock being open, a quantity of mercury is poured into the open end, and the surfaces of the mercury A a will of course stand at the same level in both limbs of the tube. The two columns of air, A C and a D, sustain a pressure equal to the weight of a column of air continued from A and a to the top of the atmosphere. If we now close the stop-cock D, the effect of the whole weight of the atmosphere above that point is cut off, so that the surface a can sustain no pressure from the weight of the atmosphere. The level of the mercury, however, remains the same, because the elasticity of the column of air a D, is equal to the weight of the whole column before this small length was cut off. Under this condition of the experiment, it may be said that the surface A is pressed by the *weight* of the whole atmospheric column, and the surface a, by the *elasticity* of a portion of air which has been subjected to the weight of the whole atmospheric column; and that these two different properties of the atmosphere, its weight and its elasticity, exactly counterbalance each other; because the pressure of the atmosphere on A is transmitted to the surface a, and the elasticity of the confined portion of air on a is transmitted to the surface A, thus producing equilibrium.

Fig. 18.



We have seen that the pressure of the air is equal to about $14\frac{1}{2}$lbs. on the square inch. This pressure will sustain a column of mercury 30 inches high and an inch square; or in other words, the weight of such a column of mercury is equal to about $14\frac{1}{2}$lbs. Now if we pour an additional quantity of mercury into the long limb, so as to compress the air in a D into half its former limits, that is, until the surface of the mercury rise from a to b, and then draw a horizontal line from b to the opposite point b' in the longer limb, it will be found that the column of mercury b' B required to compress the air in a D to half its former limits, measures exactly 30 inches, the weight of which is equal to the atmospheric pressure. The force with which the surface b is pressed upwards towards D is therefore equal to *two atmospheres*, or double the force with which a was pressed upwards towards D. Consequently the elasticity of the confined column b D, is double its former elasticity or that which it had when filling the space

ministers, assembled at the diet of Ratisbon. The force of two teams, each consisting of a dozen horses made to pull in opposite directions, was found insufficient to separate the hemispheres.

a D, so that when air is compressed into half its volume its elasticity is doubled. On again pouring mercury into the tube at C until the air in the shorter limb is reduced to a third of its bulk as at c D, the compressing force will be equal to 3 atmospheres, and the height of the column of mercury would extend to C or 60 inches above the level c. If we wish to compress the confined air into one-fourth part of its original volume, mercury must be poured in to the height of 90 inches, and then the elastic force of the confined air would be 4 times greater than at first.

It appears from these experiments that *the elastic force of air varies in exactly the same proportion as its density.* This important law, named, after its discoverer, the *law of Mariotte*, applies not only to air, but to all gaseous bodies when subject to such variations of pressure as can be readily obtained. Air has been allowed to expand into more than 2,000 times its usual bulk, and compressed into less than a thousandth of its usual bulk; but at these extreme degrees of rarefaction or condensation, it is difficult to determine its elasticity with rigour, so that it is uncertain whether the law of Mariotte applies so extensively. It is probable that when gases are subjected to very great compression, their density increases in a greater ratio than their elasticity; but Mariotte's law has been found to apply to air when condensed as much as 50 times, and also when allowed to expand to several times its usual volume.

The elasticity of the air is taken advantage of in the construction of those useful instruments, the exhausting syringe and the air-pump. The exhausting syringe consists of a brass cylinder, fig. 19, with an accurately fitting piston. The lower part of the cylinder contains two valves, one a opening upwards into the cylinder, and the other b at the side opening out into the air. The vessel V to be exhausted is screwed into a short tube projecting from the cylinder. On closing the stop-cock of this vessel and drawing up the piston, a vacuum or empty space must evidently be left between the bottom of the cylinder and the piston. Then on opening the stop-cock, the air in the vessel no longer being counterbalanced by the atmospheric pressure, expands by its elasticity, forces open the valve a and fills the empty space below the piston. On driving the piston forcibly down so as to condense the air the valve a is closed and b is forced open, and through this valve b the contents of the cylinder are expelled. When the piston has been thus forced to the bottom of the cylinder it is again drawn up, and the stop-cock being left open, the air from the vessel expands and follows it all the way; but the external air cannot enter through b, because this valve opens outwards, and the external atmospheric pressure only serves to close it more securely. On again depressing the piston the valve a is closed and b is forced open; and in this way the action is carried on until the air left in the vessel is so greatly expanded that its elasticity is insufficient to open the valve at a. The *exhaustion* of the vessel is then said to be complete. It must, however, be evident that a perfect vacuum cannot in this way be formed in the vessel. A small portion of air must always be left in it, and this portion can easily be calculated. If the cylinder be of the same capacity as the vessel, and the weight and friction of the valve be regarded as nothing, one half of the air will pass out of the vessel by the first stroke of the piston; the remaining half will still completely fill the vessel, but its atoms or particles will be further apart; its density will be diminished one half, and its elasticity will be diminished in the same proportion. The second stroke of the piston will again diminish the air in the vessel by one half, and the air left after the second stroke will have one-fourth of its former density and elasticity. The following table will show the progress of the exhaustion during nine strokes of the piston; the quantity of air in the vessel before the first stroke being taken as unity.

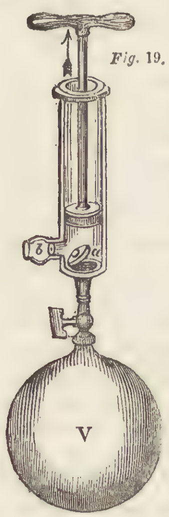


Fig. 19.

Stroke.	*Goes out.*		*Left in Vessel.*	*Elastic force of the remainder.*	
1st,	$\frac{1}{2}$ of 1	=	$\frac{1}{2}$	15 in. of mercury,	or 7.35 lbs. per sq. in.
2d,	$\frac{1}{2}$ of $\frac{1}{2}$	=	$\frac{1}{4}$	$7\frac{1}{2}$ in. of mercury,	or 3.675 ,,
3d,	$\frac{1}{2}$ of $\frac{1}{4}$	=	$\frac{1}{8}$	$3\frac{3}{4}$ in. of mercury,	or 1.837 ,,
4th,	$\frac{1}{2}$ of $\frac{1}{8}$	=	$\frac{1}{16}$	1.875 in. of mercury,	or 0.918 ,,
5th,	$\frac{1}{2}$ of $\frac{1}{16}$	=	$\frac{1}{32}$	0.9375 in. of mercury,	or 0.459 ,,
6th,	$\frac{1}{2}$ of $\frac{1}{32}$	=	$\frac{1}{64}$	0.4687 in. of mercury,	or 0.229 ,,
7th,	$\frac{1}{2}$ of $\frac{1}{64}$	=	$\frac{1}{128}$	0.2344 in. of mercury,	or 0.114 ,,
8th,	$\frac{1}{2}$ of $\frac{1}{128}$	=	$\frac{1}{256}$	0.1172 in. of mercury,	or 0.057 ,,
9th,	$\frac{1}{2}$ of $\frac{1}{256}$	=	$\frac{1}{512}$	0.0586 in. of mercury,	or 0.028 ,,

Hence it appears, that after the ninth stroke, the air left in the vessel will be only $\frac{1}{512}$th of its original quantity, and as it still occupies the same space, it has only $\frac{1}{512}$th the original density and elastic force, which is equal to a pressure of only 0.028lb. to the square inch, which would scarcely be sufficient to raise the valve. If however the valve a be fastened to the piston by a loose string, so long that it may become tightened just before the piston reaches the top of the cylinder, the string will open the valve, and the exhaustion may be carried much further.

The air pump, Fig. 20, is a double exhausting syringe, but the valve through which the air is forced out of the cylinder, instead of being placed in the side of the cylinder, as at b, Fig. 19, is contained in the piston or plug itself. The cylinders, or *barrels*, as they are called, are placed side by side, and motion is given to their pistons by means of a toothed wheel and racked piston rods, so contrived, that while one piston is ascending and drawing out the air, the other is descending and expelling the air already withdrawn from the vessel under exhaustion. At the bottom of each barrel is a valve opening upwards, so that during the ascent of either piston, the air below the valve

forces it open and fills the barrel. During the descent of either piston this valve is closed, and the valve in

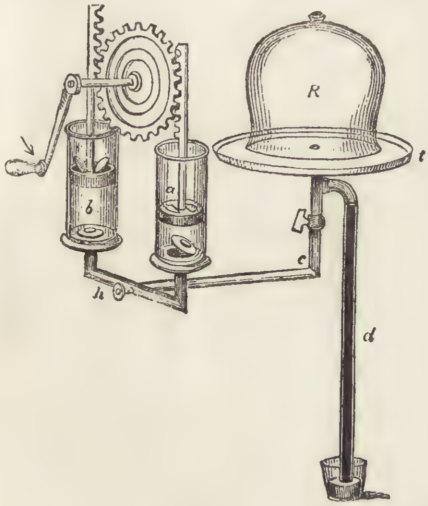


Fig. 20.

the piston itself opening upwards, allows the escape of the air between the bottom of the barrel and the piston. The vessel to be exhausted is called a *receiver*, R; it is made of stout glass, with a thick rim at the bottom, which is ground perfectly smooth, and is smeared over with pomatum before being placed on the metal *table t*, thus ensuring air-tight contact therewith. The receiver thus forms a transparent chamber, in which any substance or arrangement of apparatus adapted to the purpose may be observed under any amount of rarefaction that may be given to the inclosed air. The table is perforated in the centre with a hole which communicates by a bent metal tube *c* with the barrels *a b*. This tube has a stop-cock, which, when closed, prevents any air from leaking into the receiver from the barrels, and when open, allows them to communicate with the inclosed air. When the experiment is over, air can be re-admitted into the receiver by a hole in the bent metal tube at *h*; this hole is closed by a thumb-screw, and is made air-tight by a washer of leather. In order to ascertain the amount of exhaustion in the receiver, one extremity of a bent glass tube, *d*, opens into the metal tube *c*, and the other extremity dips into a cistern of mercury. This tube, which is more than 30 inches long, acts as a gauge, and indicates by the ascent of the mercury within it the amount of rarefaction in the receiver. As the pump is worked, the air in the receiver diminishes in density and consequently in pressure, so that the external atmospheric pressure on the surface of the mercury in the cistern forces some of the metal up the tube. The weight of the column of mercury thus raised, combined with the elastic pressure of the air remaining in the receiver, is equal to the atmospheric pressure, and the elastic force of the air in the receiver is equal to the excess of the atmospheric pressure above the weight of the column of mercury in the tube. If a common barometer stand at 30 inches, and the mercury in the gauge at 20 inches, the pressure of the air in the receiver is equal to 10 inches of mercury or one-third of that of the external atmosphere. The density of the air in the receiver is also one-third of that of the external air, showing that two-thirds of the air have been removed. In the best air pumps, the valves at the bottom of the barrels are not opened by the elastic force of the air, but by a mechanical contrivance working in the piston rods.

AIR-BEDS AND CUSHIONS. The elasticity of the air is taken advantage of in applying it as a stuffing material for cushions, pillows and beds. A textile fabric is rendered air-tight by the application of a solution of India rubber, and when made up into the required form, the seams are rendered tight by means of the same substance. At one corner is a short tube fitted with a screw, by loosening which the bag can be distended, and by tightening it the air is prevented from escaping. If too much air be introduced, the pillow or cushion becomes too hard, but when moderately distended, it is a tolerably soft surface. When not in use, the air can be let out and the cover folded up into a small space. The principal objection to its use arises from its great heat: air being a bad conductor of heat, the enclosed air, when made warm by contact with the body, retains its warmth and produces an unpleasant sensation of dry heat to the part which rests upon it. The water-bed or water-cushion is a much softer and cooler article, and has in great measure superseded air-beds and cushions.

AIR-GUN. The exhausting syringe, Fig. 19, may also be used as a condensing syringe. If the vessel be removed from the end of the syringe and screwed into the short tube *b* at the side, it will be evident that on drawing the piston to the top of the cylinder, air will rush through the valve *a* and fill it. On depressing the piston, the valve *a* will close and the valve *b* will open, so that the air contained in the cylinder will be forced into the vessel V through the valve *b*, and if the vessel be strong enough it will accommodate this increased quantity of air without bursting. On again raising the piston to the top of the cylinder, a fresh supply of air will fill it, and on again depressing the piston an additional quantity will be forced into the vessel. Each succeeding descent of the piston will, however, become more difficult, for the air contained in the cylinder will not force open the valve *b* until it is more compressed than the air within the vessel, which presses up against the valve *b*. On closing the stop-cock and removing the vessel from the syringe, we have a volume of condensed air which will rush out with great force the moment the stop-cock is opened, and this force has been used for projecting balls or other missiles.

In the air-gun, the vessel for containing the condensed air is a strong metal ball furnished with a small hole and a valve opening inwards. This ball is screwed to a barrel containing a bullet, when upon turning a cock and opening a communication between the condensed air and the bullet, the latter will be projected forward with a greater or less velocity

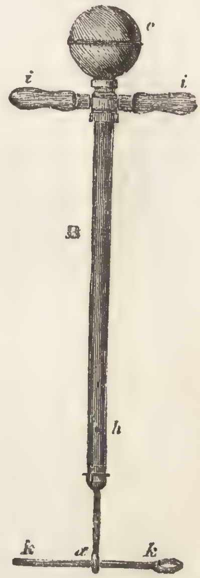
according to the state of condensation and the weight of the bullet. In air-guns, the reservoir of condensed air is usually very large in proportion to the tube which contains the ball, so that its elastic force is not greatly diminished by expanding through it, and the ball is urged all the way by nearly the same uniform force as at the first instant. The elastic fluid arising from inflamed gunpowder, on the contrary, is very small in proportion to the barrel of the gun, and occupies only a narrow space next the butt-end; so that by dilating into a comparatively large space as it urges the ball along the barrel, its elastic force is proportionately weakened, and it acts always less and less on the ball in the barrel. "Whence it happens, that air, condensed into a pretty large machine only 10 times, will project its ball with a velocity but little inferior to that given by gunpowder; and if the valve of communication be suddenly shut again by a spring after opening it tc let some air escape, then tne same charge may serve to impel several balls in succession. In all cases where a considerable force is required and consequently a great condensation of air, it will be requisite to have the condensing syringe of a small bore, perhaps not more than half-an-inch in diameter, otherwise the force requisite to produce the compression will become so great that the operator cannot work the machine; for as the pressure against every square inch is about 15lbs., and against every circular area of an inch diameter 12lbs., if the syringe be an inch in diameter, it will require a force of as many times 12lbs. as the density of the air in the receiver exceeds that of the common atmosphere; so that when the condensation is 10 times, the force required will be 120lbs., whereas with a half-inch bore it will only amount to 30lbs."[1]

There are various forms of air-gun, but perhaps the best is Martin's, Fig. 21. It consists of a lock, stock, barrel, ramrod, &c. of about the size and weight of a common fowling-piece. Under the lock at *b* is screwed on a hollow copper ball (*c*) perfectly air-tight. This ball is charged with condensed air by means of the syringe, Fig. 22. When the ball is charged and screwed on, and a bullet is rammed down in the barrel, if the trigger *a* be pulled, the pin in *b* will by the spring-work within the lock strike into the copper ball, and thereby suddenly pushing in the valve within it, let out a portion of the condensed air, which rushing up through the aperture of the lock, and forcibly striking on the bullet, will propel it to the distance of 60 or 70 yards, or further if the air be strongly condensed. The gun may in this way be discharged many times before the condensed air has lost its propelling power.

The air is condensed in the copper ball by screwing it to the top of the syringe. At the lower end of the rod *a* is a stout ring, through which passes the rod *k*, upon which the feet are firmly placed; the hands are then applied to the two handles *i i* fixed on the side of the barrel of the syringe, when by moving the barrel B steadily up and down on the rod *a*, the ball *c* will become charged with condensed air. The end of the rod *k* has a square hole, which with the rod serves as

Fig. 21.

Fig. 22.



a key to fix the ball fast to the screw *b* of the gun and syringe. When the barrel is drawn up the air will rush in at the hole *h*, and when it is pushed down the air contained in it will have no other way to pass from the pressure of the air-tight piston but into the ball *c* at the top. The barrel being drawn up the operation is repeated until the condensation is so strong as to resist the action of the piston.

In other forms of air-gun there are two barrels, one of small bore from which the bullets are shot, and a larger barrel on the outside of it which forms the reservoir of condensed air: the stock of the gun contains the syringe for condensing the air. The ball is inserted by means of the rammer, and by pulling a trigger a valve is opened which allows the air to come behind the ball so as to drive it out with great force. If this valve be opened and shut suddenly, one charge of condensed air may make several discharges of bullets; but if the whole of the air be discharged on a single bullet, it will impel it more forcibly.

The air-gun is sometimes made in the form of a cane or walking-stick. Fig. 23. It is then called

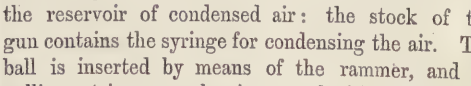


Fig. 23.

an *air-cane*. It is the same in principle as the air-gun, but the syringe is applied to the end of the barrel *c*, and the lock and trigger are shut up in a brass case, and when the discharge is made the trigger is pulled by pulling the chain *b*. There is a round chamber for the condensed air at the end of

(1) Encyclopædia Metropolitana. Article, Pneumatics.

the string at *e*, furnished with a valve which acts in a similar manner to that of the copper ball. When not in use the brass case *d* is slid off, and the instrument then becomes a walking-stick. The head of the cane unscrews at *a* where the extremity of the piston-rod in the barrel is shown. An iron rod is placed in a ring at the end of this, and the air is condensed in the barrel in a manner similiar to that of the air-gun, but its force is not so great as in that machine.

The first notice of the modern air-gun is in the "Elémens d'Artillerie" of David Rivaut, who was preceptor to Louis XIII. of France. He ascribes the invention to Marin of Lisieux, who presented one to Henry IV. It appears, however, that Ctesibius, an Alexandrian Greek, who lived B. C. 150—120, applied the elasticity of the air to the construction of *wind-guns;* but in these machines the ball was not immediately exposed to the action of the air, but was impelled by the longer arm of a lever, while the air acted on the shorter. The air-gun is now seldom used, and indeed it must be regarded chiefly as a scientific toy, except in those cases, which we should hope are of rare occurrence, where it has been made the instrument of private revenge.

ALABASTER. [See GYPSUM.]

ALBUMEN or ALBUMINE, (from the Latin *albumen*, the white of an egg,) an organic nutritive principle, the chief ingredient in the white of eggs (ovalbumine), and in the fluid portion of the blood (seralbumine). It also occurs in the sap or juices of many vegetables, as the potatoe, carrot, turnip, cabbage, asparagus, &c.; in the seeds of the cereal grasses; in almonds, filberts, oily nuts, the houseleek, &c. The most characteristic property of albumine is that of solidifying or *coagulating* when exposed to a moderate heat, in which state vegetable albumine, that from potatoes for example, is not to be distinguished from boiled white of egg.

Animal albumine is that which is chiefly employed in the useful arts, and we shall confine our attention to it. The albumine of eggs and of blood is associated with certain inorganic salts and a small portion of free soda, which gives it an alkaline reaction, and renders it soluble in the animal system. Albumine deprived of its alkali is no longer soluble. Ovalbumine is a thick glairy fluid, denser than water, without taste or smell, and dissolves readily in cold water. Exposed to atmospheric air it soon putrefies, but if a thin layer be spread out and exposed to evaporation in a warm place it dries up to a pale yellow, brilliant gum-like substance, in which state it may be preserved for any length of time, the presence of water being in all cases necessary to putrefactive fermentation.

When white of egg is exposed to heat it gives out a peculiar and characteristic odour. At about 134° white fibres of coagulum begin to appear; at 160° it becomes a solid mass. At 212° it dries, shrinks, and assumes the appearance of horn. In proportion as albumine is diluted with water it requires a higher temperature to coagulate it; but water with only one-thousandth part of its weight of albumine is rendered opaque by boiling. If the quantity of albumine be so great that the liquid appears slimy, a heat of 145° or 150° is sufficient to render the whole solid, white and opaque; but in a very dilute state the albumine separates in light flocks. After coagulation albumine is no longer soluble in water, but it dissolves in caustic alkali. The only chemical change that can be traced in coagulated albumine is the loss of alkali and soluble salts, which are removed by the hot water.

From its property of coagulating by heat, albumine is used to clarify syrups, and other liquids. The albumine is first mixed with the liquid to be clarified, and heat is gradually applied; the albumine coagulates in every part of the liquid, and entangles with it all the minute insoluble substances which render the liquid cloudy, and carries them to the surface in the form of a scum which can be removed. Albumine may also be employed as a clarifier at ordinary temperatures for wine, beer, &c., in which case it unites with the tannine, and forms an insoluble compound which acts in the same manner as coagulated albumine. But for this purpose isinglass acts much better.

Albumine is also coagulated by alcohol, which unites with the water which held the albumine in solution, and it is precipitated in white filaments. It is also coagulated by sulphuric, hydrochloric, and nitric acids, but not by acetic acid, for this dissolves it. Metallic salts, such as muriate of tin and subacetate of lead, also coagulate it; bichloride of mercury, or corrosive sublimate, is on this account a delicate test of the presence of albumine, for if a single drop of the saturated solution of this salt be allowed to fall into water containing only the two-thousandth part of albumine, it will occasion a milkiness in the water, and a curdy precipitate. Albumine is an effective antidote in cases of poisoning by corrosive sublimate. It should be administered in the form of fluid white of egg, one white being required to neutralise the effect of 4 grains of the poison.

Albumine is also coagulated by voltaic electricity. If a fluid containing it be exposed to the action of a voltaic battery, soda will appear at the negative pole, and albumine will coagulate round the positive pole.

Albumine contains in 100 parts:—

Carbon	54.84
Hydrogen	7.09
Nitrogen	15.83
Oxygen	21.23
Phosphorus	0.33
Sulphur	0.68
	100.00

The presence of sulphur is shown by a boiled egg blackening a silver spoon; a trace of alkaline sulphuret being formed or separated during the coagulation.

Lime, baryta and strontia form insoluble compounds with albumine, which harden on drying. A lute formed by mixing slaked lime with white of egg,

and spread on strips of paper or linen, is useful in making tight the joints of chemical apparatus.

ALCOHOL (an Arabic word) is the spirituous portion of fermented liquors, sometimes called *ardent spirit.* [See FERMENTATION, and, for its composition, ETHER. See also ACETIC ACID.] By carefully distilling fermented liquors the alcohol, mixed with a portion of water, can be separated, forming a product the properties of which differ according to the substances from which it is derived. Thus, the fermented and distilled juice of grape yields *brandy;* that of the sugar cane, *rum;* the wort of barley, which is generally malted for the purpose, yields *whisky* and *spirits of wine.* The *rectified* spirit of wine of the London Pharmacopœia contains about 82 parts of absolute alcohol and 18 of water. Its specific gravity is directed to be 0.838. To obtain pure or *absolute* alcohol, the spirit of wine must be mixed with some substance which has a strong affinity for water and little or no affinity for alcohol. Thus, carbonate of potash is a deliquescent salt; that is, when exposed to the air it attracts moisture therefrom, and dissolves, or deliquesces: it therefore has a great attraction for water; but it is quite insoluble in alcohol. When, therefore, dry carbonate of potash is added to rectified spirit of wine, the water of the spirit dissolves the salt, and forms a dense solution upon which the alcohol floats. It is not, however, quite free from water, for, when poured off and distilled, it still contains about 5 per cent. of water. Alcohol of the specific gravity of 0.835 may by this treatment be reduced to 0.815. Powdered quicklime may be substituted for the carbonate of potash with greater advantage; but it must be left for three or four days in contact with the spirit, in a well stoppered bottle, and be occasionally shaken. Chloride of calcium, fused in order to get rid of its water, may also be employed for separating water from alcohol. Equal weights of the spirit and the salt must be mixed in a well-stoppered bottle, and, when the salt is dissolved, the clear solution is poured into a distilling apparatus, and distilled at a moderate heat. About half the quantity of spirit employed must be sent over, and the process then be stopped. This will be absolute alcohol. Its specific gravity at 60° is 0.794.

There are other methods by which spirit may be deprived of a portion of its water. Thus, if a quantity of brandy or other strong spirit be put into a bladder, or into a wide-mouthed bottle and tied over with bladder, and be exposed to a temperature of from 105° to 120°, the aqueous portion will pass through the membrane in preference to the alcoholic, and in this way the spirit may be made stronger. Smugglers, who carry spirits about their persons in bladders, are aware of this fact; and this explains why their customers prefer the smuggled to the legitimate article, on account of its being stronger than ordinary spirit. Spirit of wine, of the specific gravity of 0.867, has in this way been reduced to 0.817. But by this process of exosmose absolute alcohol cannot be procured.

Alcohol is a limpid colourless liquid, of an agreeable odour and a strong pungent taste. In its pure state it is poisonous, and when diluted produces intoxication. It is extremely inflammable, burning with a pale bluish flame, the heat of which is intense. When diluted with water the heat of the flame is less intense, and its colour more yellow. It produces no smoky deposit, and the products of combustion are carbonic acid and water. According to Saussure, jun., the combustion of 100 parts of alcohol produces 136 parts of water. The intense heat of the flame and the absence of any smoky deposit make alcohol so useful in the spirit-lamp of the chemist. The flame may be coloured by certain salts: boracic acid and salts of copper give it a green colour; salts of baryta yellow; and the salts of strontia an intense red. Alcohol has never been frozen. When exposed by Faraday to a temperature of 166° below the zero of Fahrenheit's scale, it thickened considerably, but did not congeal. Hence the great use of spirit thermometers for measuring low degrees of temperature. The low temperature thus obtained by Faraday was by a mixture of solid carbonic acid and ether; but it is stated by another authority that spirit of wine, of the specific gravity 0.820, entirely congeals under similar circumstances. The boiling point of alcohol, specific gravity 0.7947, is 173°, under an atmospheric pressure of 29.5. The boiling point varies with the specific gravity, that is, it becomes higher for each addition of water. Under the exhausted receiver of an air-pump, alcohol boils at common temperatures. The rate of expansion under the influence of heat is such that 1,000 measures of alcohol (specific gravity 0.817) at 50° become 1,079 measures at 170°.

Absolute alcohol has so great an affinity for water that it absorbs it rapidly from the atmosphere, and sensibly increases in specific gravity in a short time. It combines with water in all proportions; and the mixture gives rise to a diminution in bulk, and a considerable disengagement of heat in consequence of the increased density. Equal parts of alcohol (specific gravity 0.825) and water, each at 50°, when suddenly mixed, give rise to a temperature of 70°; and equal measures of proof spirit and water, each at 50°, give a temperature of 60°.

The uses of alcohol in the arts are very numerous. It can be used as a solvent in cases where water altogether fails. It dissolves resins, and hence its use in varnish-making. It does not readily unite with the fixed oils, except castor oil; but it freely dissolves the essential oils and camphor, and hence its use in pharmacy and perfumery. It dissolves sugar, soap, and oxalic, tartaric, gallic, benzoic, and some other acids. It is extensively used in the preparation of ether. From its great attraction for moisture it is employed in preserving vegetable and animal substances, and anatomical preparations. It is valuable to the chemist as a fuel, and also for many purposes of chemical analysis; but its high price in this country is an impediment in the way of science and the useful arts.

Alcohol is an agreeable stimulant in fermented drinks; but the want, suffering, and disease occa-

sioned by its abuse far outweigh any benefits likely to be derived from its use, as forming part of a beverage. The quantity of alcohol in wine, beer, &c., is very variable. According to Professor Brande, port and sherry, and some other strong wines, contain from 19 to 25 per cent. of alcohol; the lighter wines of France and Germany, about 12 per cent. Strong ale contains about 10 per cent.; ordinary spirits, as brandy, gin, and whiskey, 40 to 50 per cent., or occasionally more. The latter owe their peculiar flavours to certain essential oils which are present in very small quantity, and are generated during fermentation, or are purposely added. The strength of such spirituous liquors as consist of water and alcohol may be judged of by the taste, the size and appearance of the bubbles, when shaken, the sinking or floating of olive oil in them, and the appearances they exhibit when burned; for, if the spirit burns away to dryness, and inflames gunpowder, or a piece of cotton immersed in it, it is considered as alcohol. "The different spirituous liquors leave variable proportions of water, when thus burned in a graduated vessel. But it must be recollected that in rum, brandy, and several other spirits, the specific gravity is often interfered with by extractive, colouring, and saccharine substances, often fraudulently added, with a view to increase the specific gravity, and therefore to diminish their apparent strength. In examining these liquors, they should be distilled, and the specific gravity of the distilled portion will then give an indication of the proportion of alcohol that may be relied on. In respect, however, to the excise, distillation is inconvenient, and is therefore only resorted to in extreme or suspicious cases."—*Brande.*

The only correct mode of ascertaining the specific gravity of liquids is by weighing them against an equal volume of pure water at the same temperature. [See SPECIFIC GRAVITY.] In practice, however, the hydrometer is used; and the form of the instrument, and the method of using it for the purposes of the excise, were given in the report of a Committee of the Royal Society to the Government. The following extract from this report will afford much useful information on this subject, especially as relates to the composition and density of *proof spirit,* which is defined by 58 George III. c. 28, to be such "as shall, at the temperature of 51° Fahr., weigh exactly twelve thirteenth parts of an equal measure of distilled water." The term *proof spirit* usually means a mixture of equal bulks of alcohol and water; but the specific gravity of such a mixture will depend upon that of the standard alcohol, which is not specified in the act referred to; but it appears, that equal weights of alcohol, specific gravity 0.796 at 60°, and water, have a specific gravity of 0.917, which is very nearly that of legal proof spirit.

The Report says:—"With regard to the substance, alcohol, upon which the excise duty is to be levied, there appears to be no reason, either philosophical or practical, why it should be considered as *absolute.* A definite mixture of alcohol and water is as invariable in its value as absolute alcohol can be. It is also invariable in its nature, and can be more readily, and with equal accuracy, identified by that only quality or condition to which recourse can be had in practice—namely, specific gravity. A diluted alcohol is, therefore, that which is recommended by us as the only excisable substance; and as, on the one hand, it will make no difference in the identification, and, on the other, will be a great commercial advantage, it is further recommended, that the standard be very nearly that of the present proof spirit.

"The proposition of your Committee is, that standard spirit be that which, consisting of alcohol and water alone, shall have a specific gravity of 0.92 at the temperature of 62° Fahr., water being unity at that same temperature; or, in other words, that it shall, at 62°, weigh $\frac{92}{100}$ths, or $\frac{23}{25}$ths of an equal bulk of water at the same temperature. The temperature of 62° Fahr. is recommended as the standard, because it is that at which water was taken in the late national survey and adjustment of weights and measures. The specific gravity of 0.92 is taken rather than 0.918633, (the specific gravity of present proof spirit at 62°,) because the fraction expressing its relation to water is much more simple, and will facilitate the construction of the tables and the verification of the instruments proposed to be used.

"This definition of standard spirit appears to your Committee to be very simple, and yet as exact as it can be, or as any other standard spirit can be. This standard is rather weaker than the old proof spirit, in the proportion of nearly 1.1 gallon of the present proof spirit per cent. But this disadvantage your Committee consider as trifling, compared with the great convenience which will result if the specific gravity of 0.92 be taken rather than 0.918633.

"It may be interesting hereafter to ascertain what proportion of absolute alcohol enters into the composition of the recommended standard spirit, should the latter be adopted by the Government; but the point possesses not the slightest practical importance in relation to the present question. The proposed standard is, in fact, more definite, more sure, and more ascertainable than that of the alcohol which it must contain. Philosophers are not yet agreed upon the density of absolute alcohol; and the differences of specific gravity assigned to it vary from 0.7910 to 0.7980. But, assuming the truth to be somewhere within these extremes, the proposed standard would contain nearly one-half, by weight, of absolute alcohol.

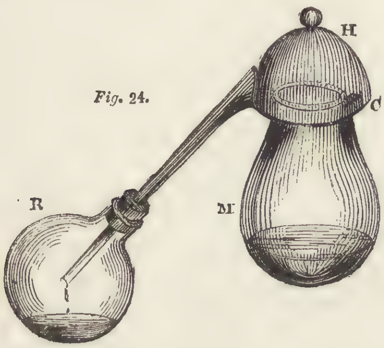
"In any mixture of alcohol and water, the specific gravity appears to be the only quality or condition to which recourse can be had for the practical purposes of the Excise, in order to indicate the proportion of standard spirit present. Your Committee are of opinion, that the hydrometer is the instrument best fitted, in the hands of the excise officer, to indicate that specific gravity; and they think it ought to be so graduated, as to give the indication of strength, not upon an arbitrary scale, but in terms of specific gravity at a fixed temperature, which, in the present case, should be 62°, or that of the standard spirit. The graduation, in terms of specific gravity, will not

only supply a very minute, yet sensible scale, for the purposes of ascertaining smaller differences in the density than is done by the present scale, but will also afford an easy means of verifying the instruments when required."—[See HYDROMETER.]

ALE. [See BREWING.]

ALEMBIC. A vessel used for the distillation or sublimation of substances of moderate volatility. In its simplest form it consists of a *body, cucurbit,* or *matrass,* M (Fig. 24) containing the fluid to be distilled, or the substance to be sublimated; a head or capital, H, furnished with a pipe, leading into a receiver R.

Fig. 24.



Heat is applied to the body M, either by means of a lamp or a sand-bath. The rising vapour is condensed in the head, and, trickling down the sides, is received into its depressed channel C, from which it flows down the pipe into the receiver, which is loosely fitted to it by means of a ring of cork. The condensation is more rapid if the receiver be immersed in cold water. The alembic is now seldom used, it having been superseded by better forms of apparatus, which will be described under DISTILLATION.

ALKALI. A term applied by the Arabians to the carbonate of soda found in the ashes of marine plants. The same term was afterwards extended to carbonate of ammonia, and also to the carbonate of potash found in the ashes of land plants, which was long considered as identical with carbonate of soda. It was discovered that these three alkaline carbonates are rendered much more caustic by contact with lime; and hence the *mild* (or carbonated) alkalies were distinguished from the *caustic* (or pure) alkalies. Dr. Black, in 1756, showed that this change is due to the abstraction of carbonic acid from the mild alkalies by the action of lime. The older chemists distinguished ammonia as the *volatile alkali* from the two *fixed alkalies,* and of these potash received the name of *vegetable alkali,* soda that of *mineral alkali,*—the one being found chiefly in the ashes of plants, the other in rock-salt. It was afterwards found that potash exists in many widely diffused minerals; and, consequently, the term *vegetable alkali* could not properly be applied to it. Klaproth suggested that the word *kali* should be used to designate it; but the French chemists invented the word *potasse* to distinguish the pure alkali, deriving the term from the German word, *pottasche,* which, probably, owes its origin to the use of iron pots in burning the materials from which the alkali is obtained. The alkalies and earths were long regarded as simple substances, although Lavoisier had suggested that they were metallic oxides. Sir Humphry Davy, in 1807, first succeeded, by means of a powerful voltaic battery, in separating the metals from potash, soda, baryta, strontia, and lime, and in obtaining traces of metallization from the earths. These results were extended and confirmed by Gay-Lussac, and others. The discovery of these metals also led to that of pure potash and soda; for, up to that time, these substances were known only in the state of hydrates, and these hydrates were long regarded as anhydrous alkalies.[1]

Alkalies have a great affinity for acids, combining with them to form salts. Alkalies in solution convert vegetable blue colours into green, and vegetable yellows into reddish brown. The infusions of red cabbage, and of turmeric, or bibulous paper stained with these substances, are used as tests for the presence of an alkali. Unsized paper, tinged by a strong infusion of the petals of the red rose, is a very delicate test for the presence of an alkali: in a very strong alkaline solution, it is turned greenish brown; but when the solution is very dilute, its reaction is very delicate, and it becomes bright green; it will thus indicate the presence of an alkali when turmeric paper is not visibly discoloured. The alkalies restore the colour of vegetable blues which have been reddened by acids; and acids restore vegetable colours which have been altered by alkalies.

No metal yields two alkalies by different degrees of oxidation, nor does any one become, by this process, an alkali and an acid. All the fixed alkalies will bear a high temperature without decomposition. They are of extensive use in various chemical arts, as in the manufacture of SOAP and GLASS.

There is a class of vegeto-alkalies, named *alkaloids,* which are produced in plants during vegetation, but always in combination with a peculiar acid. They are, for the most part, sparingly soluble in water, but dissolve in hot alcohol, from which they often crystallize, in a very beautiful manner, in cooling. Two of them, however, are oily, volatile liquids. Their taste, in solution, is intensely bitter; and their action on the animal economy is very energetic. They all contain nitrogen, and are complicated in structure. None of the organic bases occurring in plants have hitherto been formed artificially. *Morphia* or *morphine,* the chief active principle of morphine, and *cinchonia* and *quina,* to which the valuable medicinal qualities of the Peruvian barks are due, may be cited as examples of alkaloids.

ALKALIMETRY. A process for estimating the quantity of free alkali, or of carbonate, contained in any impure specimen. The process depends on the neutralization of the alkali by an acid, and the use of the test-papers, described in the last article. The dilute acid is usually placed in a graduated glass tube, called an *alkalimeter,* (Fig. 25,) which

(1) Gmelin's Hand-Book of Chemistry, vol. iii.

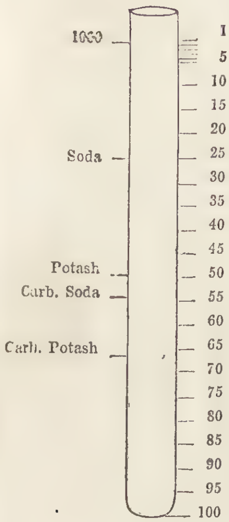


Fig. 25.

is prepared and used in the following manner, according to the directions given by Dr. Faraday in his work on "Chemical Manipulation." A tube, closed at one end, $9\frac{1}{2}$ inches long, and $\frac{3}{4}$ of an inch internal diameter, is selected, and 1,000 grains of water are weighed into it. The space thus occupied is graduated into 100 equal parts, and every ten divisions are numbered from above downwards. At 23.44 parts, or 76.56 parts from the bottom, an extra line is made on the opposite side, with the word *soda* written against it with a scratching diamond. Lower down, at 48.96 parts, is another line, with the word *potash*. Still lower, at 54.63 parts, is a third line, with *carb. soda* marked; and at 65 parts, a fourth, marked *carb. potash*. It will be observed, that portions are measured off beneath these marks, in the inverse order of the equivalent numbers of these substances, and, consequently, directly proportionate to the quantities of any particular acid, which will neutralize equal weights of the alkalies or their carbonates. As these points are of importance, they ought to be verified, by weighing in the tube first 350, then 453.7, then 510.4, and, lastly, 765.6 grains of water, which will correspond with the marks if they are correct. Or the graduation may be laid down from the surface of the four portions of fluid, when weighed in, without reference to where they fall upon the general scale. The aperture of the tube should be so formed as to be perfectly and securely covered by the thumb of the left hand.

The acid used with the tube is diluted sulphuric, of the specific gravity 1.1268, prepared by mixing 1 part by weight of oil of vitriol, of specific gravity 1.82, with 4 parts of water. A quantity of this acid measured into the tube up to any one of the four marks described will neutralize 100 grains of the dry alkali or carbonate set down at the mark; consequently, if water be added in the tube thus filled up to any one of the marks, until the 100 parts are full, and the whole uniformly mixed, 1 part of such diluted acid will neutralize 1 grain of the alkali or carbonate named at the mark up to which the tube was first filled with the acid of specific gravity 1.1268.

When a specimen of potash, barilla, or kelp is to be examined, 100 grains are to be weighed out, dissolved in warm water, filtered, the insoluble portion washed, and the solution added to the rest. By this process the alkali will be separated from carbonate of lime, or other insoluble matters, which might otherwise lead to error in the estimation. The alkaline solution is to be put into a basin in the sand-bath, and the tube and acid prepared. The acid is to be poured into the tube up to the mark which indicates the substance to be tested for; *potash* or *carbonate of potash* for the potash or pearlash of commerce, and *soda* or *carbonate of soda* for barilla or kelp. Water is then added until the 100 parts are filled up, and, closing the tube with the thumb, its contents are to be perfectly agitated and mixed. Then inverting the tube, so that the thumb and mouth of the tube are downwards, the acid is to be let out gradually into the alkaline solution in the basin, by relaxing the thumb, and admitting a succession of small bubbles of air. The hot solution beneath is to be continually stirred, so as to mix the acid instantly with the whole, and increased caution must be used as the point of neutralization is approached. The acid must then be let out in portions less than a drop. This process is carried on until the alkali is found by test papers to be exactly neutralized. Then the tube must be inverted, the thumb removed by drawing its under surface over the edge of the tube, so as to leave as much as possible of the fluid that otherwise might adhere to it; and having allowed the sides to drain, it must be observed how many parts of acid have been used, the number of which will indicate the number of grains of the alkali or carbonate contained in the 100 grains of the impure alkali operated with.

The proper strength of the acid used in the above process may be ascertained in the following manner: crystals of bicarbonate of potassa are fused in a platinum crucible, and when cold a portion of the resulting solid, 70, 80, or 100 grains, is to be weighed in water, thus furnishing a known weight of pure carbonate of potash in solution. The solution is then to be diluted, heated, and neutralized by acid from the tube, diluted as before described from the mark of carbonate of potassa. If it be found that as many parts of the acid have been used as of grains of the carbonate weighed out, the acid is of proper strength; if more acid has been used, it is too weak; if less has been sufficient, it is too strong.

A process of neutralization, quite the same in principle, may be adopted for the purpose of estimating the strength of acids. This is called *Acidimetry*. Acetic acid is frequently estimated in this way, both because its specific gravity varies very little with its strength, and because it is much used in the arts in an impure state. As there is a very near agreement between the equivalents of acetic acid and carbonate of lime, by allowing the acid to act on fragments of marble, the quantity dissolved will at once express the quantity of pure acid present. In like manner hydrochloric, nitric, and any other acid which forms a neutral soluble salt with lime, may be estimated, and its strength become known. Thus, let 500 grains of the acid be put into a basin or flask with 100 grains of marble, in fragments, and, after the first effervescence is over, warmed, and the neutrality ascertained by test papers; the solution is then to be poured off, and the remaining pieces of marble washed, dried, and weighed. The number of grains of carbonate of lime dissolved in hydrochloric acid, multiplied by 0.74, indicate the number of grains of dry acid by

which it has been dissolved; and the number dissolved in nitric acid, multiplied by 1.08, also represent the equivalent of dry nitric acid, or the quantity present in the solution submitted to experiment.

ALKANET. A fine red dye, obtained from the roots of a kind of bugloss (*Anchusa tinctoria*), largely cultivated about the neighbourhood of Montpellier, and in some other parts of France. The dye is procured solely from the bark of the roots, therefore young plants, in which there is more bark in proportion to the bulk of the root than in old ones, are the most valuable. The colour is yielded readily to alcohol and to all unctuous substances, but to water it yields only a dull brown colour. The principal use of alkanet is to colour ointments, lip-salve, pomade, &c. The spirituous tincture is also employed in staining white marble.

ALLOY. Chemistry has made us acquainted with about forty-three metals, of which not more than twelve are of great and extensive use in the industrial arts. These are iron, copper, lead, tin, silver, gold, mercury, zinc, platinum, arsenic, antimony, and bismuth. In this limited list platinum is always employed in a pure state; iron, copper, lead, tin, silver, gold, and zinc, are also employed in certain cases in their pure state; but in all those applications where hardness is a desirable quality two or more metals are combined, so as to form an alloy.[1] Arsenic, antimony, and bismuth are too brittle to be used in a pure state.

Although the number of useful metals is so limited, the number of alloys admits of being increased to almost any extent. Thousands of alloys are possible, but hitherto not more than two or three hundred have been made; and of this number not more than about sixty have been studied with care. As it is impossible to predict the properties of a new alloy, it remains for the scientific chemist or the manufacturer to add to our knowledge on this interesting subject.

An alloy may be regarded as a new metal, since it does not always, or even generally, represent the properties of its component parts, or the mean of those properties, which it would do if it were a mechanical mixture, as it is sometimes stated to be. The power of forming alloys is highly valuable to the manufacturer, because it enables him to create, as it were, a new metal, adapted to some of those special wants which advancing civilization is constantly suggesting to mankind. When, for example, the idea of printing with movable types had been clearly conceived, the most obvious metals for the purpose were iron, copper, tin, and lead. But the first two were found too hard, and cut the paper pressed upon them; the other two were too soft, and were flattened under the action of the printing press. At length it was discovered that by making an alloy of 1 part antimony, and 3 or 4 of lead, a new metal was produced, harder than lead, and softer than iron and copper, and which fulfilled all the conditions required. It is stated by most writers on this subject that type-metal expands, instead of contracting, in passing from the fluid to the solid state; and that, were it not for this property, type could not be cast in a mould, but that each letter must be cut separately, thereby increasing the expense of printing, perhaps a hundredfold, and diminishing the benefits of this glorious art in a far greater proportion.

The Editor has recently been led to doubt this statement, from the circumstance that the French stereotype casters cast their plates with the moulds in a vertical, instead of a horizontal, position, thereby getting a hydrostatic pressure, which assists in filling up the mould, and producing the sharpness required. In the usual method of casting type, the mould for each letter consists of two pieces of steel, kept asunder by means of a spring, but fitting accurately together when the spring is pressed between the thumb and fingers. This mould is held in the left hand of the caster; with an iron spoon in the right hand he takes up a portion of the melted metal, pours it into the mould, gives it a sudden upward jerk, in order that the metal may penetrate every portion of the mould; at the same instant he closes the mould upon the fluid mass, still further compressing it, and suddenly causing it to solidify by contact with the two comparatively large masses of metal which form the two sides of the mould. He then relaxes the spring, and shakes out the solid type. In this way eight or ten letters are cast per minute.

Now, in this operation, the fluid type-metal is made to undergo two distinct acts of compression, first by the jerk of the mould, and secondly by closing the mould upon the fluid mass, so as to compress it into a somewhat smaller space than it would otherwise occupy; and, while thus compressed, the mass of metal surrounding it chills it, and causes it to solidify. It is, we think, to this circumstance that the sharpness of type is owing, and not to its expanding in the act of cooling. There seems to be no doubt that type-metal does not contract in cooling so much as either of its constituents in passing separately from the fluid to the solid state; but that it does contract, and not expand, seems to be proved by the fact, that when small globules of molten type-metal cool, they leave a small cup or indentation at the upper part. The Editor has undertaken some experiments to determine this interesting point, and will state the results in a future article.

In filling up and bringing into contact the neighbouring parts of machinery, such as round the brass nuts in the heads of some screw-presses, lead is found not to answer, on account of its great contraction in cooling; but the alloy of lead and antimony answers very well: not, as we think, because it expands in cooling, but because it does not contract so much as lead alone.

In the example of type-metal we see that the properties of the two metals are greatly modified. Lead is a soft, malleable metal; antimony is hard, brittle, and crystalline. The alloy is flexible, harder than lead, and softer than antimony; but, by varying the proportions of the two metals, the properties of the alloy become varied also. 6 parts lead to 1 of anti-

(1) When mercury is one of the metals thus combined the combination is called an AMALGAM.

mony produce an alloy used for large, soft printers' types; 3 of lead and 1 of antimony produce the metal of the smaller types: the former will bend slightly, but the latter is very hard and brittle, and will not bend at all. With larger proportions of lead a flexible alloy is obtained, adapted to the sheathing of ships. In these examples the properties of the alloy are modified by the properties of the constituent metals: when the soft lead prevails, the alloy resembles lead; by increasing the proportion of antimony the alloy becomes harder and more brittle. With 4 of lead and 1 of antimony the fracture of the resulting alloy is not reluctant like lead, nor foliated like antimony, but is nearly of the grain and colour of some kinds of steel and cast-iron. So also in alloys of tin and lead, the former contributes to the alloy some of its hardness, whiteness, and fusibility in proportion to its quantity, as in the various kinds of pewter; but in this alloy, copper and sometimes zinc or antimony are introduced in small portions.

In these examples the properties of the constituents appear to be only modified. In other examples we get new sets of properties. Thus, copper and tin are both very malleable and ductile metals. An alloy of 9 parts copper and 1 part tin is a tough, rigid metal, used in brass ordnance, and called *gun-metal;* it admits of neither rolling nor drawing. By increasing the proportion of tin, which is much softer than copper, we actually increase the hardness of the alloy. One-sixth of tin produces the maximum degree of hardness. With one-fourth of tin the highly elastic and sonorous *bell-metal* is produced, in which the brittleness rather than the hardness is increased. 2 parts copper and 1 part tin produce an alloy so hard that it cannot be cut with steel tools, but crumbles under their action; when struck with a hammer, or even suddenly warmed, it flies in pieces like glass, and displays a highly crystalline structure. It has no trace of the red colour of copper, but is quite white, and takes an exquisite polish, not greatly disposed to tarnish: this is the *speculum-metal,* used in reflecting telescopes.

Two parts copper and one part lead produce an inferior metal named *pot-metal* or *cock-metal,* which is so soft as frequently to be broken in driving a tap into a beer-cask.

Copper and lead do not combine so readily as copper and zinc; for if the moulds be opened before the castings become cold the lead will ooze out, and appear on the surface in globules. The same thing happens to a less extent in gun-metal, where the tin "strikes to the surface," and renders it particularly hard at those parts, from an increased proportion of tin. Moulds of brass, on the contrary, may be opened while red-hot.

The properties of an alloy may also be varied by the addition of a small quantity of a third metal. For example: brass is an alloy of copper and zinc; but the best kind of brass for turning at the lathe is made by the addition of a small quantity of lead. This, however, renders it unfit for hammering, just as brass without lead is unfit for turning.

Alloys are formed in various ways. Many are prepared by fusing the two metals in a covered crucible; but if the metals differ considerably in specific gravity, the heavier one will often sink, and the lower part of the bar or ingot will differ in composition from the upper. This may, to a great extent, be prevented by stirring the alloy with a rod of pottery ware until it solidifies. An alloy of gold and copper cast into bars, the moulds being placed perpendicularly, it was found that the upper part of the bar contained more copper than the lower. Copper and silver appear to combine easily; but it is very difficult to form a bar of their alloy of perfectly uniform composition.

In casting large bells and cannons the bottom of the casting will sometimes contain too much copper, and the top too much tin. In such case the objects must be broken and remelted, and this second fusion often corrects the defects of the first. In most alloys of three metals it is best to combine them first in pairs, and then to fuse these pairs together. For example, it is not easy to unite iron and bronze by a direct method; but if tinned iron and bronze be fused together, they unite readily. When lead is to form part of the composition of brass, it is better to melt the lead and the zinc together, and then to add this alloy to the melting copper.

When the component parts of an alloy are separately fused and mingled together, great heat is generally evolved: thus, when zinc and copper are suddenly mixed, in the proportion to form brass, the increase of the heat is so great as to vaporize part of the zinc.

The specific gravity of an alloy is seldom the mean of its component parts. In some cases there is an increase of density; in others a diminution. In the following table, prepared by Thenard, the list on the left hand contains those alloys which have a greater specific gravity, and the right hand list those which have a less specific gravity, than the mean of their components.

Increased Density.	Diminished Density.
Gold and zinc.	Gold and silver.
Gold and tin.	Gold and iron.
Gold and bismuth.	Gold and lead.
Gold and antimony.	Gold and copper.
Gold and cobalt.	Gold and iridium.
Silver and zinc.	Gold and nickel.
Silver and lead.	Silver and copper.
Silver and tin.	Copper and lead.
Silver and bismuth.	Iron and bismuth.
Silver and antimony.	Iron and antimony.
Copper and zinc.	Iron and lead.
Copper and tin.	Tin and lead.
Copper and palladium.	Tin and palladium.
Copper and bismuth.	Tin and antimony.
Copper and antimony.	Nickel and arsenic.
Lead and bismuth.	Zinc and antimony.
Lead and antimony.	
Platinum and molybdenum.	
Palladium and bismuth.	

Alloys conduct heat and electricity, but less perfectly than the pure metals of which they are formed. Alloys are in general less ductile than the more ductile of their constituents. Alloys formed of ductile metals are either brittle or ductile. When formed in nearly equal proportions of their constituents, there are as many ductile as there are brittle alloys; but when one of the metals of an alloy greatly predominates, it is usually ductile. By combining ductile metals

with brittle ones, brittle alloys are usually formed, if the brittle metal predominates, or even if its proportion be about equal to that of the ductile metal. But when the ductile metal is much greater than the brittle one, the alloy is nearly always ductile. All alloys formed of brittle metals are themselves brittle.

Lead, tin, or zinc, alloyed with the less fusible metals, copper, gold, and silver, produce alloys less malleable, when cold, than the superior metal, and, when heated barely to redness, they fly to pieces under the hammer: hence, brass, gun-metal, &c., when hot, require cautious treatment. Muntz's patent metal, which is a species of brass, can, however, be rolled at a red heat; but it must be remembered that the action of rollers is far more regular than that of the hammer, and soon gives rise to the fibrous character which, when uniformly distributed, is the element of strength in metals.

The strength or cohesion of alloys is in general greatly superior to that of their constituents. Thus the relative weights required to tear asunder a bar one inch square of each of the following alloys is given in the subjoined tables from Muschenbroëk's investigations:—

Strength of Alloys.

10 Copper,	1 Tin	32,093 lbs.
8 ,,	1 ,,	36,088 ,,
6 ,,	1 ,,	44,071 ,,
4 ,,	1 ,,	35,739 ,,
2 ,,	1 ,,	1,017 ,,
1 ,,	1 ,,	725 ,,

Strength of Cast Metals of which the above Alloys were composed.

Barbary Copper	22,570 lbs.
Japan Copper	20,272 ,,
English Block Tin	6,650 ,,
Ditto	5,322 ,,
Banca Tin	3,679 ,,
Malacca Tin	3,211 ,,

These results show that theory and practice agree in assigning the proportion of 6 to 1 as the strongest alloy. The most reflective mixture is the weakest but one, its strength being only one-third to one-sixth that of tin, or one-twentieth that of copper, which latter metal constitutes two-thirds its amount.

In the following alloys, which are the strongest of their respective groups, the tin is always four times the quantity of the other metal; and they all confirm the remarkable fact that alloys have for the most part a greater degree of cohesion than the stronger of their constituents.

Strength of Alloys.

4 English Tin,	1 Lead	10,607 lbs.
4 Banca Tin,	1 Antimony	13,480 ,,
4 ,,	1 Bismuth	16,692 ,,
4 English Tin,	1 Zinc	10,258 ,,
4 ,,	1 Antimony	11,323 ,,

Strength of their constituent Cast Metals.

Lead	885 lbs.
Antimony	1,060 ,,
Zinc	2,689 ,,
Bismuth	3,008 ,,
Tin	3,211 to 6,650 ,,

All the metals, even the most refractory, which can scarcely be fused in a crucible at the greatest heat of the furnace, melt down with ease when surrounded by the more fusible metals. The surfaces of the superior metal are dissolved or washed down, layer by layer, until the whole becomes liquefied. Thus nickel is nearly as difficult of fusion as iron; but it is usefully employed with copper in German silver, to which it gives whiteness and hardness, and renders the alloy less fusible. Platinum is a very refractory metal, being infusible at the highest heat of a furnace; yet it combines so readily with zinc, tin, and arsenic, that it is dangerous to heat one of those substances in a platinum spoon, for an alloy would probably be formed, and the spoon spoiled.

Alloys are without exception more fusible than the superior metal which enters into their composition. Hard solders are usually made of the same metal they are intended to join, with the small addition of a more fusible metal. It may even be said that the fusing point of an alloy is generally lower than that of the *less* fusible metal which enters into its composition. When the constituent metals are nearly of the same fusibility, the alloy still fuses at a temperature lower than the fusing point of the less fusible metal. An alloy, very remarkable for its easy fusibility, is formed by combining 8 parts of bismuth with 5 of lead and 3 of tin. This alloy fuses in boiling water, and even in water at the temperature of 198° or 200° Fahr. And yet, if we calculate the fusing point by taking the mean of the fusing points of the constituents multiplied into their mass, this will give 520°, for bismuth melts at 500°, lead at 600°, and tin at 442°, and

$$\frac{8 \times 500 + 5 \times 600 + 3 \times 442}{16} = 520.$$

Sir Isaac Newton was the discoverer of this remarkable alloy, which is called *fusible metal.* His proportions were 5 parts bismuth, 3 parts tin, and 2 parts lead. By combining these three metals in various proportions, alloys are formed of various degrees of fusibility above and below the temperature of boiling water. Safety-plugs for steam-boilers have been formed in this way. A hole made in the boiler is stopped with one of these plugs, and it was supposed that if from any cause, such as the derangement of the safety valve, steam above the usual temperature and pressure be formed, it would fuse the plug of fusible metal, and thus force its way out through the aperture instead of bursting the boiler. [See BISMUTH.] If mercury be added to the constituents of fusible metal, the alloy is still more fusible, and is sometimes used for filling the hollows of decayed teeth.

When an alloy is left to itself after having been fused, it solidifies and crystallizes in a confused manner, and often separates into different layers of varying degrees of density.

In exposing an alloy which contains a volatile metal to a heat greater than that which is necessary to fuse it, it is in some cases decomposed, but generally not completely. A portion of the volatile metal is driven off, but a portion also still remains, and forms a stable compound with the less volatile metal.

Alloys are in general less acted on by the atmospheric air, than the metals of which they are composed. There are, however, certain exceptions, as for example, plumber's solder, which contains 2 parts

lead and 1 part tin, burns at a red heat, and with 3 parts lead and 1 part tin it is even more combustible. An alloy of antimony and iron is so easily set on fire, that the mere action of the file is sufficient for the purpose. An alloy of chromium and lead will sometimes take fire spontaneously by mere exposure to the air, and always at a slight elevation of temperature.

When an alloy is formed of a metal which absorbs oxygen, and another which is not oxidizable, the first may be converted into an oxide, and the second retains its metallic state. This is one of the methods adopted for separating silver from lead. If both the metals of an alloy absorb oxygen, both may be converted into oxides; but if one of the two oxidizes more readily than the other, the latter may be separated almost in a pure state by suspending the operation at a certain point. In this way copper may be separated from tin.

In forming an alloy it is often necessary to protect one or both of the metals from the action of the atmosphere. Thus in combining tin and lead, resin or grease is usually put on the surface of the melting metals. In combining tin with iron, as in tinning cast-iron kettles, &c., sal-ammoniac is rubbed upon the surfaces of the hot metals in contact with each other, and thus the air is excluded; while, if any oxide is formed, it combines with the acid in the sal ammoniac, and the surface of the metal is kept bright. [See SOLDERING.]

ALUM is a double salt, of great use in the arts, especially for preparing mordants in dyeing and calico-printing. It is also used in preparing and preserving skins; in candle-making, for hardening and whitening the tallow; in paper-hanging it is mixed with the paste; and it is also of use in pharmacy.

The word *alumen* occurs in Pliny's Natural History, in which it is stated that different substances were so named, all characterised by a certain degree of astringency, and all employed in dyeing and in medicine. It has been supposed from Pliny's account that the alum of the ancients was sulphate of iron or sulphate of alumina, or a mixture of the two. The ancients do not seem to have been acquainted with our alum. It appears to have been first manufactured in the East, but at what place or period is not known. About four or five hundred years ago there was a manufacture of alum at Rochha, the Turkish name of the government which comprehends Edessa, whence the name *roch* or *rock alum*, still in use. It was also manufactured near Smyrna and Constantinople. The first alum works in Europe are said to have been established in 1460, at Tolfa, about 6 miles from Civita Vecchia, in the territory of the Pope. The first alum works established in England were at Gisborough, in Yorkshire, in the reign of Elizabeth. Pennant says that they were first discovered by Sir Thomas Chaloner, "who observing the trees tinged with an unusual colour, made him suspicious of its being owing to some mineral in the neighbourhood. He found out that the strata abounded with an aluminous salt. At that time the English being strangers to the method of managing it, there is a tradition that Sir Thomas was obliged to seduce some workmen from the Pope's alum works near Rome, then the greatest in Europe. If one may judge from the curse which his holiness thundered out against Sir Thomas and his fugitives, he certainly was not a little enraged, for he cursed by the very form that Ernulphus has left us, and not varied a tittle from that most comprehensive of imprecations. The first pits were near Gisborough, the seat of the Chaloners, who still flourish there notwithstanding his holiness's anathema." It is curious to notice after this, that in later times the proprietors of the English alum works farmed those of the apostolic chamber, and increased in various ways the benefit derived from them.[1]

The constituents of alum are sulphuric acid, alumina, an alkali and water. The alkali may be potash, soda or ammonia. Hence there are three distinct kinds of alum, depending on the alkali employed. In this country potash alum is the kind most in use. In France both potash and ammonia alum are manufactured. Soda alum occurs native in different parts of the world, especially in South America, where soda almost uniformly replaces potash; for instead of nitrate of potash, which occurs in many parts of the old continent, there are large deposits of nitrate of soda in South America.

In alum works the most important minerals employed in extracting the salt, are *alum stone, alum slate* and *bituminous shale.* The processes vary according to the nature of the mineral. Alum stone is of a white or greyish colour, and sometimes yellowish white. It contains all the constituents of alum. In the works at Tolfa it is obtained by blasting with gunpowder. If the stone be kept constantly moistened with water for about two months, it will fall to powder and yield alum by lixiviation. This, however, is not the method adopted. The alum stone is broken into small pieces, and piled on the top of a perforated dome, within which a wood fire is kindled. As the roasting proceeds a sulphurous odour is disengaged, owing to the decomposition of a portion of the sulphuric acid of the stone. The roasting is performed twice, the pieces of ore which were at the edge during the first roasting being put into the middle during the second roasting. The heat requires to be carefully regulated, for if too strong the calcined stone will not yield any alum, and if not strong enough, the stone does not readily fall to powder. By this operation the stone acquires a reddish colour. It is next arranged in rows between trenches of water, and sprinkled frequently so as always to be kept moist. In two or three days it falls to powder, but the watering is continued every day for a month. The powder thus produced is then thrown into a leaden boiler filled about two-thirds with water. It is frequently stirred during the boiling, and water is added as the evaporation goes on. When the solution is complete the fire is withdrawn, and the earthy matters allowed to subside. A cock is then opened,

(1) Beckmann: History of Inventions.

and the clear liquor drawn off into deep wooden square vessels, so constructed as to be easily taken to pieces. In these vessels the alum gradually crystallizes, and attaches itself to the sides and bottom of the vessel. The mother liquor is drawn off into shallow wooden troughs, where a fresh crop of crystals is deposited. The liquor is now of a red colour, and is muddy, and the last crystals are mixed with this red substance. They are washed clean, and the mother liquor is pumped up into a trough, and used in subsequent processes. The alum thus produced is named *Roman alum,* and is highly esteemed on account of its superior purity, some other kinds of alum being contaminated by the presence of iron. Roman alum is always mixed with a little reddish powdery matter, which is easily separated. This was probably first derived from the mother liquor, and was popularly esteemed as a proof of the alum being genuine. Hence, Dr. Thomson supposes that the manufacturers add a red powder to the article after or during the process of manufacture.

Alum slate is a much more abundant mineral than alum stone. It occurs abundantly with transition slate, and is found at Whitby, and other parts of Great Britain. The alum district of Whitby consists of precipitous cliffs, bordering on the sea, and extending to a distance of about thirty miles along the coast of the German Ocean. It is a slaty rock, but sometimes occurs in balls; it is of a bluish-black colour, with a strong shade of grey. On exposure to the air, it effloresces, and acquires an aluminous taste. Being different in composition to alum stone, it requires a different treatment in the manufacture of alum from it. If it contain much lime or magnesia, it does not answer the purpose of the manufacturer. The essential ingredients are alumina and iron pyrites. The first process is to roast the ore. In Sweden, where the alum slate itself contains a large quantity of combustible matter, it is used as fuel in the roasting. A thin layer of brushwood is first covered with pieces of alum slate, and set on fire: as the combustion proceeds, new layers of alum-slate are added, in alternate layers of roasted and unroasted ore. At Whitby, coal is used as fuel. The effect of this operation is to decompose the pyrites, to convert the sulphur into sulphuric acid, and to oxidize the iron. The ore is then washed with water, to dissolve the sulphate of iron and the sulphate of alumina. For this purpose, it is put into reservoirs of wood or of masonry, and the water is left during twelve hours to act upon ore that has been twice lixiviated; the solution is then drawn off by a stop-cock in the bottom of the reservoir, and allowed to remain twelve hours on ore that has been once lixiviated. It is then left for twelve hours upon fresh ore. The solution is now saturated with sulphate of alumina and sulphate of iron, and has a specific gravity of 1.25 at the temperature of 55°. The liquor is next boiled in leaden vessels to the crystallizing point. In Sweden, the alum slate is used as the fuel, whereby the double purpose is served of evaporating the liquor and roasting the ore. During the boiling, oxide of iron falls, mixed with sulphate of lime, if lime be present. When sufficiently concentrated, the liquor is let into square reservoirs, to crystallize. Large quantities of crystals of sulphate of iron are deposited, and these are collected by drawing off the liquor into another reservoir. When all the sulphate of iron that can be separated in this way is removed, a quantity of sulphate of potash, hydrochlorate of potash, or of putrid urine, is mixed with the liquor. By this addition, alum is formed in the liquor, and it gradually deposits itself in crystals on the sides of the vessel. These crystals are collected, and dissolved in as small a quantity of boiling water as can be used for the purpose, and the solution is poured into large wooden casks. In two or three weeks, the crystals of alum cover the sides and bottom of the vessel. The hoops are then taken off, and the staves of the casks removed, and an enormous mass of alum crystals, of the shape of the cask, is left standing, as in Fig. 26. The mass is then

Fig. 26. ALUM CRYSTALLIZING VATS.

pierced, to allow the mother liquor to run out. This is reserved for another operation, and the alum, being broken to pieces, is fit for the market.

Another substance from which alum is manufactured is bituminous shale. This is a slaty mineral, generally accompanying beds of coal, and, consequently, is very common in Great Britain. It is of a brownish-black colour, and when heated, burns with a pale flame and a sulphurous odour, and then becomes white. In the large alum works at Campsie, near Glasgow, the shale is extracted from the old abandoned coal-pits in the neighbourhood, which are very extensive. This shale is described as a clay, mixed with some coal, and with that variety of iron pyrites which undergoes decomposition, and is converted into sulphate of iron by exposure to the air. The sulphate of iron thus formed acts slowly on the clay, and, in course of time, converts it into sulphate of alumina. During a long period, alum was formed from this material by simple lixiviation with water; and a large quantity of this washed shale accumulating

in the neighbourhood of the works, it was subjected to the operation of burning, and thus made to produce a new crop of alum.

The manufacture of alum from bituminous shale and slate clay resembles the manufacture from alum slate. In the old coal-pits above alluded to, the air is moist, and the usual temperature about 62°. The shale thus exposed, during many years, has gradually opened, in the direction of its slaty fracture, so as to resemble a half-shut fan, and all the chinks are filled with a saline efflorescence. The salt, which is a mixture of sulphate of iron and sulphate of alumina, is white, with a shade of green, and has a sweetish astringent taste. The salts are dissolved by lixiviating the shale with water. The lixiviated ore being left exposed to the weather above ground, forms more salt, which is gradually washed out by the rain, and the water is collected and preserved for use. The liquor is concentrated by boiling in vessels of stone, or of brick, the heat being supplied by a current of hot air blown over the surface. When sufficiently hot, potash is stirred in, which converts the sulphate of alumina into alum. Formerly, chloride of potassium, a refuse of the soap-boilers, was used for the purpose; but of late years, at least at Hurlet, near Glasgow, sulphate of ammonia, from the liquor obtained from the gas-works, has been used. In general, the alum made at Hurlet contains both potash and ammonia; but the manufacturer can supply it free from potash. Such ammonia alum is convenient to chemists, because, when it is heated to redness, every thing is driven off except pure alumina.

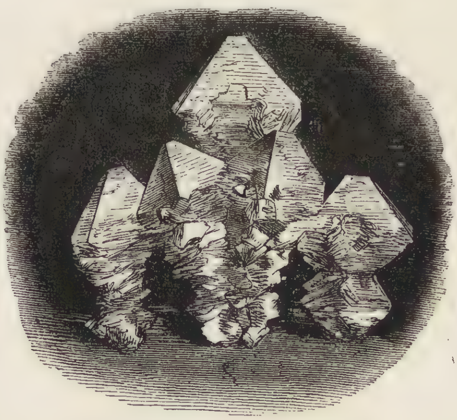
When the alkali has been added, the liquor is let out into another trough, where it crystallizes; but as there is a sulphate of iron in the solution, this must be got rid of; and the method of doing so is to draw off the mother liquor at the proper time; for the alum being much less soluble in water than sulphate of iron, crystallizes first, so that the sulphate of iron is drawn off in the mother liquor while still in solution. The first crystals of alum are impure, and of a yellow colour, and partly impregnated with sulphate of iron. These are dissolved in hot water, and the solution is poured into troughs, where it crystallizes a second time. These second crystals are washed repeatedly with cold water, which separates any remaining sulphate of iron; for this, as already stated being much more soluble in water than alum, dissolves first. These second crystals are then dissolved in hot water, and the hot concentrated solution poured into large casks, the surface of which is covered with two cross beams. As the liquor cools, a vast number of alum crystals form on the sides and surface. The casks are allowed to remain until cold, and this requires from eleven to fourteen days. The alum is then removed, and is ready for the market. The impure sulphate of iron obtained in this process is roasted at a strong heat, and when washed, yields more alum. The red residue is ground to a fine powder, and when dried, is used as a Venetian-red pigment. By altering the temperature at which it is dried, a *yellow* ochre is obtained instead of a red.

In France, where alum ores are not abundant, alum is manufactured from clay. The clay is well ground, and mixed with half its weight of the saline residue obtained from a mixture of sulphur and nitre, which is little more than sulphate of potash. The mixture is formed into balls about five inches in diameter, and calcined in a furnace. The balls are next placed on the floor of the chamber in which sulphuric acid is made. The acid vapour causes them to swell and open on all sides. In about a month they are sufficiently penetrated by the acid. They are then removed, and exposed to the action of the air, under sheds, where the saturation becomes more complete. They are then lixiviated with water, and the clear liquid, by evaporation, yields pure alum. Such is the method formerly adopted at Montpellier; but it is now found sufficient to sprinkle the balls with a quantity of sulphuric acid, of the specific gravity 1.367, equal to the weight of clay employed. The solution takes place with great facility, and crystals of alum are obtained by evaporating the liquid.

Another method is, to mix 100 parts clay with 50 of nitre and 50 of sulphuric acid. This mixture is put into a retort and distilled. Aquafortis comes over, and the residue in the retort on being lixiviated with water yields excellent alum. In 1842 Dr. Turner took out a patent for making alum from felspar.

Alum prepared by any of these processes is a white transparent salt, crystallized in regular octohedrons of which the apices are more or less truncated. Fig. 27 represents a group of crystals from one of the crystallizing tubs shown in Fig. 26.

Fig. 27.



12 parts of alum dissolved in boiling water with 1 part of slaked lime, yield *cubical* crystals on cooling. A slight addition of potash to a solution of alum also causes the formation of *cubic alum*, as it is called. The taste of alum is sweet and astringent, and its action decidedly acid: it dissolves metals with evolution of hydrogen as readily as free sulphuric acid. Its specific gravity is 1.72. It dissolves in about 15 parts of cold water, and in about its own weight of boiling water. The crystals effloresce slightly in a dry atmosphere; when heated they fuse in their water of crystallization at a temperature

below 212°, and when this water is driven off by heating the alum in a crucible, it swells up above the mouth of the crucible, as shown in Fig. 28, and the dry alum becomes opaque and spongy, in which state it is called *burnt alum*. Burnt alum is a mild escharotic.

Fig. 28.

Crystallized potash alum consists of 1 atom of sulphate of alumina, 1 of sulphate of potash, and 24 atoms of water; or of 1 of alumina, 1 of potash, 4 of sulphuric acid, and 24 of water.

According to McCulloch,[1] the shipments of alum from Whitby, in 1841, amounted to 3,237 tons. He estimates the produce of the Hurlet works at about 1,200 tons a year. Alum is largely manufactured in China, and is thence exported to all the western Asiatic countries. In 1837, 2,120 tons were exported from Canton.

ALUMINA is an earth of common occurrence in the mineral kingdom, in a state of silicate, as in felspar and its associated minerals, and in the various modifications of CLAY thence derived. It is the oxide of a metal which has been named *aluminum*, and may be obtained in a pure state by decomposing potash alum by means of carbonate of potash, repeatedly washing the precipitate with hot water; redissolving it in hydrochloric acid, adding ammonia in excess, edulcorating and drying the precipitate: it is rendered anhydrous by exposure to a red heat. Pure alumina may also be obtained by igniting pure ammonia alum previously deprived of its water of crystallization by heat; sulphate of ammonia evaporates and alumina remains in the form of a perfectly white powder, soft to the touch and insoluble in acids. Its extreme divisibility and the great hardness of its particles might render it useful for polishing metals, and its whiteness fit it for the preparation of colours. Alumina is insipid and insoluble. Its specific gravity is 2.0, but after exposure to intense heat it increases to 4.0. Under the oxyhydrogen blowpipe it fuses into a colourless bead. It has a strong attraction for moisture, which it absorbs from moist air to the amount of one-third of its weight. It becomes plastic when mixed with water: if dried in this state in the air and then heated it shrinks from loss of water. This is the principle of Wedgwood's pyrometer for registering very high temperatures; but as the shrinkage in different specimens of clay prepared in the same manner is not the same at the same temperatures, this instrument was of very little use in science. It has long been superseded by Daniell's pyrometer.

Alumina has a strong affinity for various organic compounds, and its use in dyeing and calico printing depends on its attraction for different colouring principles, and for ligneous fibre. If ammonia be added to a solution of alum in an infusion of cochineal or madder, the aluminous earth falls in combination with the red colouring matter, and the liquor is left colourless. Colours thus prepared are called *lakes*.

(1) Dictionary of Commerce, 1850.

Freshly precipitated alumina is readily soluble in most of the acids. The salts of alumina usually have an acid reaction. Potash and soda readily dissolve it; but it is sparingly soluble in caustic ammonia. Alumina can be recognised by its solubility in caustic potash, by the formation of crystals of alum on evaporating its sulphuric solution with the addition of sulphate of potash. It also affords a fine blue colour when moistened with nitrate of cobalt and strongly heated.

Native alumina exists in the sapphire, the oriental ruby and topaz. Corundum, adamantine spar, and emery consist chiefly of alumina with a small portion of oxide of iron and silica.

Alumina consists of 2 atoms of aluminum and 3 of oxygen.

AMADOU, a fungus, (*Boletus igniarius*,) growing from the sides of the cherry, the ash, and other trees, is prepared into a tinder by the Germans, who use large quantities of it for lighting their pipes and cigars. It is gathered in the months of August and September, and cut into thin slices, and beaten with a mallet until it is soft enough to be easily pulled asunder by the fingers. In this state it is valuable for stopping hemorrhages. To convert it into tinder it is boiled in a strong solution of nitre; it is next dried, beaten again, and boiled a second time. It can be rendered very inflammable by steeping in gunpowder water. Puff balls are sometimes made into amadou, and it is stated that the light wood of the *Hernandia guianensis* takes fire readily from a flint and steel, and is used as amadou.

AMALGAM. Mercury dissolves most of the metals, and forms a class of compounds called *amalgams*. Many of these are definite crystallizable compounds, and may be separated by gentle pressure from the superfluous mercury in which they are formed. They are usually brittle or soft. Iron and mercury may be combined by rubbing together in a mortar clean iron filings and zinc amalgam, and adding a solution of perchloride of iron; by rubbing and heating this mixture, the iron and mercury form a bright amalgam. Under ordinary circumstances iron and mercury will not unite, so that mercury is imported and kept stored in iron bottles. Amalgam of tin is readily formed by triturating the metals together, or by fusion at a gentle heat; the density of this amalgam exceeds the mean of its components It is extensively used for silvering looking-glasses. [SILVERING.] Lead and mercury unite readily in all proportions; 3 parts mercury and 2 of lead form a crystallizable amalgam. An amalgam of 3 parts mercury, 1 part lead, and 1 part bismuth is remarkable for its fluidity; it may be squeezed through leather without decomposition. It is used for silvering the inside of hollow glass spheres, previously made perfectly clean and warm. Mercury is usually adulterated with these metals. Mercury and copper may be united by a rather complicated chemical process.

All the amalgams can be decomposed at a moderate heat. Advantage is taken of this property in the art of *water-gilding*, or gilding metallic articles, such as buttons: a small portion of gold is dissolved in a

large quantity of mercury, and the articles to be gilt being made chemically clean are anointed with the amalgam, and placed in a furnace and heated; the mercury is thus driven off, and the gold is left in an exceedingly thin film on the articles. The peculiar lustre of the precious metal is brought out by burnishing. [See BUTTON. GILDING—GOLD.] *Water-silvering* is performed in the same way. Cast-iron, wrought-iron, steel, copper, and many other metals are tinned in a similar manner. An amalgam of tin is made so as to be soft and friable. The metal to be tinned is thoroughly cleaned by filing or turning, or if only tarnished by exposure it may be cleaned with emery paper used without oil, and then rubbed with a piece of coarse cloth moistened with a little hydrochloric acid. The amalgam is then rubbed on with the same rag, and all the clean parts of the metal become thoroughly coated. This process is called *cold-tinning*, to distinguish it from the usual method of tinning iron plate. [TINNING.]

In Mallet's patent processes for protecting iron from rust and corrosion, and for preventing the fouling of ships, one process is, to cover the iron with zinc. The ribs or plates for iron ships are immersed in a *cleansing bath*, formed of equal parts sulphuric or hydrochloric acid and water, used warm. The metal is then hammered and scrubbed with emery and sand to detach the scales of oxide, and to produce a thoroughly clean surface. The metal is next immersed in a *preparing bath*, consisting of a saturated solution of hydrochlorate of zinc and sulphate of ammonia; and lastly it is transferred to a metallic bath composed of 202 parts mercury and 1,292 parts zinc, both by weight. To every ton weight of this alloy is added 1lb. of potassium or of sodium, the latter being preferred. As soon as the cleaned iron has attained the point of fusion of this triple alloy, viz. 680°, it is removed, and is found to be thoroughly coated with zinc. The affinity of this alloy for iron is so intense that at the fusing heat of 680° it will dissolve a plate of wrought-iron one-eighth of an inch thick in a few seconds. When the articles to be covered are small, or the parts minute, as for example, wire, nails, or small chains, it is necessary before immersing them to permit the triple alloy to dissolve, or combine with some wrought-iron, in order that its affinity for iron may be partially satisfied, and thus diminished. In the palladiumizing process the articles to be protected are first cleansed as in zincing, and then thinly coated over with an amalgam of palladium.

A good amalgam for the use of the electrical machine is formed of 4 parts mercury, 2 parts zinc, and 1 part tin. The zinc should be melted in an iron ladle, the tin added, and afterwards the mercury, previously heated in another iron ladle, stirring the mixture with an iron rod. The amalgam should be poured, just before it solidifies, into a wooden or iron box, and be constantly agitated by shaking until cold. It should then be triturated in an iron mortar, and sifted through a small muslin sieve, so as to obtain an extremely fine powder; this being rubbed up with a little lard, is to be spread on the rubber of the electrical machine with a palate knife.[1]

AMALGAMATION. A process by which some of the ores of silver, especially the sulphurets, are reduced. The ore is washed and ground, and then mixed with a portion of common salt and roasted. Sulphate of soda and chloride of silver are formed during the operation, and these are then powdered and agitated with mercury, water and iron filings. This decomposes the chloride of silver, and the chloride of iron which is formed, is washed away; the silver and mercury unite into an amalgam, from which the excess of mercury is first squeezed out in leathern bags, and the remainder driven off by distillation. Gold is frequently extracted from its ores by the process of amalgamation.

AMBER, though classed among minerals, is of vegetable origin, bearing evidence of having been in a fluid or viscid state. It is a hard yellow substance, rather heavier than water, (its specific gravity being from 1.06 to 1.07), usually transparent when polished, but occasionally opaque or clouded. It has a resinous taste, and a smell similar to that of turpentine. It is inflammable, and gives off, while burning, a white, pungent, aromatic smoke. It possesses electric properties, which are strongly developed by friction, and which gave the name to the science of electricity, from *elektron*, the Greek word for amber. At various times the origin of amber has been a matter of dispute among naturalists, some describing it as an animal substance resembling bees'-wax, secreted by an ant inhabiting pine-forests; others maintaining it to be a fossil mineral, of antediluvian origin; and others again, with greater truth, imagining it to be a resin, oozing from the pine and afterwards solidifying. This idea was entertained by Pliny, who speaks of amber as a resinous juice, oozing from old pines and firs, and discharged by them into the sea. According to the recent researches of Göppert, amber is nothing more than an indurated resin, derived from various trees of the family of the coniferæ; which resin is found in a like condition in all zones, because its usual original depositories, viz. beds of brown coal, have been formed almost everywhere, under similar circumstances. A convincing proof that amber was once fluid is afforded by the fact that insects, leaves, drops of clear water, or portions of metal, sand, &c., are sometimes found enclosed in it. The insects are sometimes entire and in fine preservation, but frequently their detached legs and wings show that there was a hard struggle to escape from the viscid mass. Bees, wasps, gnats, spiders, and beetles, have been observed in specimens of amber; but the species more resemble insects of tropical countries than of the temperate zone. This curious circumstance of the enclosure of insects in amber has been taken advantage of by dishonest dealers, who imitate it in common copal, which closely resembles amber. Copal enclosing insects is often sold as the finest amber.

Amber is found in rounded masses, varying in size

(1) Weale's "Rudimentary Series." "Electricity," by Sir W. Snow Harris, F.R.S., &c.

from that of a nut to that of a man's head; but the latter is very rare. It is chiefly obtained on sea-coasts, after storms, when it is either picked up on the beach, or sought after by men who walk up to their necks in the waves, with long poles to which nets are attached; or it is gathered from precipitous cliffs by men in boats, who go armed with poles and iron hooks, and loosen fragments of rock in exploring them. The latter methods are not without danger to the amber-seekers. The most abundant supply of amber is obtained in East Prussia, along the coast of the Baltic, between Memel and Dantzig, and especially on the shore near Königsberg, and from Grossdirscheim to Pillau. It has also been found in Poland, Saxony, Siberia, and Greenland, and in our own country, at Cromer in Norfolk, and on the Yorkshire coast. Amber is also found in sand and clay formations; and, although not often obtained by mining operations, yet pits are occasionally sunk in sandy downs to the depth of 100 feet, and small quantities of amber thus procured.

Amber is used for ornamental purposes, but is much less esteemed in Europe than among Oriental nations, where the demand for it is very great. It is fashioned into necklaces, ear-rings, bracelets, &c., also into snuff-boxes, and the more costly kind of tobacco-pipes. For these purposes the nodules are split on a leaden plate at a turning-lathe, and brought into the required shape by whetstones, after which they are polished with chalk and water, or a vegetable oil, and completed by rubbing with flannel. The German pipe-makers, who use great quantities of amber, burn a small lamp or a little pan of charcoal beneath the amber, to warm it slightly while it runs in the lathe, to prevent it from chipping out: they also succeed in bending it by means of heat. The electrical properties of the amber become so strongly excited during these processes, that it is necessary to work with a number of pieces in succession, putting down each as it becomes hot, and liable to split from this cause. The workmen thus engaged are subject to nervous tremors, in consequence of handling continually these highly excited electric bodies.

The coarser sorts of amber, and the small pieces which cannot be applied to ornamental purposes, are used in making varnishes of a strong and durable kind, among which is the black varnish of coach-makers. The substance called *artificial musk* is nothing more than amber subjected to the action of nitric acid, which converts it into a viscid mass, having a musky odour. By distillation an acid is obtained from amber, called *succinic acid* (after the Latin and French name for amber). Sixteen ounces of amber yield about half an ounce of rough succinic acid, and rather more than 10 ounces of torrefied resin, fit for the preparation of varnish. The salts of this acid are called *succinates.*

Amber forms one of the most lucrative articles of commerce with Turkey, where the greater part of the European amber is sold; but considerable quantities are also purchased by American merchants. The revenue derived by Prussia from her trade in this article is said to be about 17,000 dollars per annum. The value of amber increases greatly with the size of the specimens: thus, a piece weighing 1 pound would fetch 50 dollars, but a piece weighing 12 or 13 pounds would be thought cheap at 5,000 dollars. There is a method, however, of cementing together small pieces of amber, by smoothing the surfaces, adding a layer of linseed oil, and pressing them together over a charcoal fire. Some large pieces of amber in the museum at Dresden are said to have been built up in this manner. A further deception is, to join pieces of copal to lumps of amber, when, from their close resemblance and equally fine polish, it is difficult to detect the imposition, except by the fracture, that of amber being conchoidal, that of copal of no determinate character. The most esteemed kind of amber is the opaque, which resembles the colour of a lemon, and is sometimes called *fat-amber.* The transparent pieces are very brittle and vitreous.

AMBERGRIS has no connexion with amber. It is a concretion from the intestines of the spermaceti whale, and is a product of disease, as it is not found in the healthy animal.

AMMONIA, or *volatile alkali,* so called to distinguish it from the *fixed* or non-volatile alkalies, potash, soda, &c., was first procured in a gaseous state by Priestley, who termed it *alkaline air.* He obtained it from sal ammoniac, whence the alkali has its present name.

Ammonia is a compound of 1 volume of nitrogen with 3 volumes of hydrogen, the 4 volumes being condensed into 2 in the state of combination. Ammonia exists in various vegetable and animal juices. Stale urine contains carbonate of ammonia, on which account this substance is used for its alkaline properties in making alum, scouring wool, &c. Ammonia is found in native oxide of iron, and in the rust of iron formed in a damp atmosphere. It is also found in charcoal, clays, and porous soils, all of which absorb it from the air, in which it is present in minute quantities, and is of importance to plants as a source of nitrogen.

Ammonia cannot be formed by the direct union of its elements, after they have assumed the gaseous state. One of them must be in a nascent state. There are several methods by which it may be obtained, but the following is common. The substances employed are sal ammoniac, or hydrochlorate of ammonia, and lime. The lime is slaked in a covered vessel, and the salt reduced to powder. Equal weights of these substances are introduced into a retort, with just enough water to damp the mixture and cause it to aggregate in lumps. On gently heating the retort, ammoniacal gas is given off in abundance, and this must be received in jars filled with and inverted in mercury. The changes which take place in the retort are as follows:—sal ammoniac is a compound of hydrochloric acid and ammonia; and the acid consists of hydrogen and chlorine. Lime is a compound of the metal calcium and oxygen. The hydrochloric acid of the salt unites with the calcium of the lime, forming chloride of calcium, which remains in the retort, while the hydrogen of the acid unites with the oxygen of the lime, and forms water.

The ammonia of the salt is thus set free, and escapes with a portion of the water last formed.

The ammonia thus produced is an aëriform body, which remains permanent under ordinary temperatures and pressures, and hence is called a *gas*. Under a pressure of 6½ atmospheres, at 50°, it becomes a colourless transparent fluid, of the density of 0.760, water being 1.000. At 103° below zero this liquid forms a white, translucent, crystalline solid, heavier than the liquid.

Ammoniacal gas is colourless, transparent, and invisible. It has an extremely pungent smell and an acrid taste. It instantly kills an animal immersed in it, but, when largely diluted with air, it is an agreeable stimulant. It extinguishes a lighted taper, but the flame becomes enlarged before it goes out. This gas is slightly inflammable, and a small jet of it will burn in oxygen gas. Mixed with an equal volume of oxygen, it burns with a feeble explosion in contact with flame or the electric spark. Its density is 0.5983, atmospheric air being unity. 100 cubic inches of ammoniacal gas weigh 18.268 grains. It acts strongly as an alkali, turning vegetable blues green, and yellows reddish brown; but, on account of the great volatility of the gas, this change is not permanent, the vegetable substances regain their colours by exposure to the air, which is not the case when changed by the fixed alkalies. Ammoniacal gas in a dry state is without action on dry vegetable colours.

Water dissolves ammoniacal gas in large quantity and with great rapidity. A few drops of water intro duced into a jar of the gas, standing over mercury, instantly condense it; a piece of ice immediately liquefies in the gas, and condenses it. Water at 50° condenses 670 times its volume of this gas, and the density of the solution diminishes as the strength increases. When water contains 9½ per cent. of the gas, its density is 0.9692; when the water is saturated, it contains 32½ per cent. of the gas, and then the density is only 0.8750. This aqueous solution is called *liquid ammonia,* and is the *liquor ammoniæ* of the Pharmacopœia. It is a colourless, transparent liquid, and has the pungency and alkaline properties of the gas. Exposed to air, ammonia escapes from it, and heat disengages it abundantly.

The presence of ammonia is detected by its strong smell, or by holding moist turmeric paper where it is suspected to exist, or by the formation of a white vapour of hydrochlorate of ammonia when exposed to a glass rod moistened with hydrochloric acid.

Ammonia is formed during the putrefactive fermentation of organic substances which contain nitrogen. Such substances contain hydrogen, nitrogen, oxygen, and carbon; the first two forming ammonia, and the last two carbonic acid. By heating animal matters (except fat, which contains no nitrogen), such as bones, hoofs, horns, &c., in iron cylinders, they are decomposed, and carbonate of ammonia is obtained, either in a solid form, or dissolved in water, and mixed with an empyreumatic oil. This liquor has a dark colour, and a pungent, disagreeable smell. When purified to separate the oil it is called *spirit of hartshorn.* The hard portion of the bone consists chiefly of phosphate of lime, which yields no ammonia; but mingled with it is a considerable quantity of gelatine, whence the ammonia is derived.

Those vegetable substances which contain nitrogen, such as the gluten of wheat, furnish ammonia by being heated. The soot of chimneys contains it. But the great supply of ammonia is from the gasworks, the ammoniacal liquor which comes over with the tar, during the destructive distillation of coal, being converted by various processes into sulphate, hydrochlorate, or carbonate of ammonia. [See GAS.]

Ammonia combines with acids, and forms salts, most of which are soluble in water, and evolve the odour of ammonia when mixed with lime or potash. Common smelling-salts are the sesquicarbonate of ammonia.

ANALYSIS, (CHEMICAL.) The object of chemical analysis is to determine the nature or composition of simple or compound substances. The composition of a substance may either be expressed in the simple elements which form its *ultimate* constitution, or it may be reduced to less complex compounds which form its *proximate* constituents. In a chemical analysis the proximate constituents are those which are usually separated. For example, alum is composed of four bodies which are in themselves compound, namely, *alumina, potash, sulphuric acid,* and *water;* and each of these consists of a pair of elementary bodies; namely, alumina is composed of *aluminum* and *oxygen;* potash, of *potassium* and *oxygen;* sulphuric acid, of *sulphur* and *oxygen;* and water, of *hydrogen* and *oxygen.* In the analysis of alum, the alumina, potash, sulphuric acid and water are the substances sought, and the elementary composition of these bodies being known, the simple elementary components of alum are also determined.

An analysis may be simply *qualitative,* in which case it is limited to the number and nature of the constituents. Thus, when alum is said to consist of sulphuric acid, potash, alumina and water, the analysis is qualitative. But when the analysis embraces the proportions by weight of the constituents, it is then said to be *quantitative.* Thus, when alum is said to contain in 100 parts 33.78 parts of sulphuric acid, 9.93 of potash, 10.82 of alumina, and 45.47 of water, the analysis is quantitative.

Two good introductory treatises on chemical analysis have lately been published, namely, "Elements of Chemical Analysis, Inorganic and Organic," by E. A. Parnell: London, 1842, and "An Introduction to Practical Chemistry, including Analysis," by John E. Bowman, Demonstrator of Chemistry in King's College, London: London, 1848. The most elaborate treatise on the subject is that by Rose.

ANCHOR, (from the Greek ἄγκυρα,) a heavy instrument let down by means of a cable to the bottom of the sea for the purpose of fixing a vessel in a harbour or road, thence called an *anchorage.* It is also of great importance to the navigator off a lee shore, and in situations where, but for its use, he might be wrecked.

The anchor in some form or other is probably as

ancient as the art of navigation itself, or at least it must have been used as soon as vessels of any considerable size were constructed. The first anchors were probably large stones, or crooked pieces of heavy wood, such as are used by the Chinese at the present day in securing their ponderous junks. When anchors came to be made of metal, they were formed at first with only one fluke; then a second was added, but no stock; afterwards each ship was furnished with several anchors, the chief one, which was called *ἱερά*, or sacred, being reserved for the last extremity. Hence arose the proverb, *sacram anchoram solvere*, or "flying to the last refuge," which has descended to us in the *sheet-anchor;* and in order to prevent this from being used except in cases of absolute necessity, it was formerly the custom to pay 5*l.* to the master on letting it go.

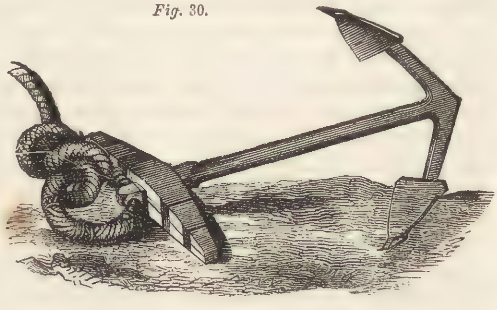
The largest ships are now furnished with seven anchors, namely, the *sheet-anchor* which, as already stated, is only let down in case of danger or during heavy gales of wind; the *bowers* or *bowyers*, which are nearly of the same size as the sheet, and distinguished as the *best bower*, the *small bower*, and the *spare anchor*. There is also the *stream-anchor*, which is much smaller than the others, and is used only for riding in rivers or moderate streams; this is one-fourth or one-fifth the weight of the others. Lastly, the *kedge-anchor*, which is half the size of the *stream*, and is only used for *kedging* in a river; that is, the anchor is conveyed by a boat up the river in advance of the ship and let down, and the ship is then hauled up to the anchor by means of the cable; the anchor is then taken up and again dropped a cable's length in advance, and the ship again moved up to it. In this way a ship may be slowly carried up a river.

In ships of war the sheet-anchor is stowed on the larboard side, with the stock vertical, and one of the flukes resting on the gangway. The bowers hang out near the ship's *bows*, and hence their name; the spare anchor is usually carried "in board." Smaller vessels, such as brigs, cutters, and schooners, have only three or four anchors.

Fig. 29.

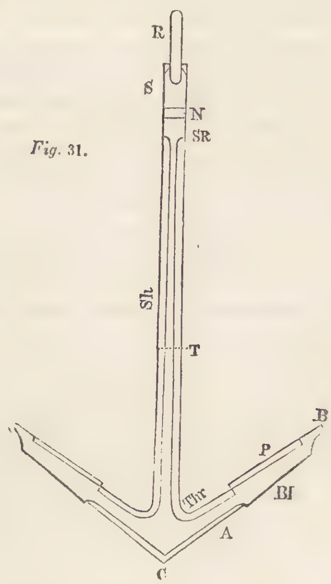
The most common form of anchor, Fig. 29, consists of two hooked or *fluked* arms, (A, Fig. 31,) for the purpose of penetrating and fixing in the soil, and a long bar or *shank*, Sh, to which the cable is attached. To the upper or cable end of the shank is a cross-beam called the *stock*, placed at right angles to the arms, and which by lying flat at the bottom causes one of the flukes to penetrate the soil more or less according to the nature of the anchorage, as in Fig. 30. The upper end of the cable being firmly secured to the ship, any strain exerted upon the cable only causes the fluke to take a deeper and firmer hold, so that the ship is held fast unless one of three things occur; the cable may give way, the arm of the anchor may snap off, or the anchor

Fig. 30.



itself may drag or plough up the soil. In some kinds of anchorage if the anchor should once start it will not take hold again; as, for example, in the Portland roads, such is the stiffness of the soil, that large lumps adhere to the fluke and prevent it from taking hold a second time. Hence the old, but absurd custom of greasing the flukes that the lumps of clay may slip off. The shank is made long in order that the stock may have greater power in directing either one or the other of the arms downwards. One end of the shank S is made square to receive and hold the stock securely in its place, and the stock is furnished with nuts or projections to keep it from shifting. The length of the square part of the shank is about one-sixth of the whole length of the shaft, and its thickness about one-twentieth. From the end of this square shank the thickness increases, but tapers towards the extremity near the arms. The part where the arms unite with the shank is called the *crown*, and the angular part between the arms and the shank is named the *throat*. A distance equal to

Fig. 31.



that between the throat Thr of one arm, and its bill B, is marked on the shank from the place where it joins the arms, and is called the *trend* T. In the

square part of the shank is a hole for receiving a ring R for the cable; this ring is lapped with cordage to prevent the chafing of the iron, but where chain cables are used, as is now generally the case, this precaution is not required.[1] The arms form an angle of about 56° with the shank, and they are made round or polygonal like the shank for about half its length, and then continued in a square shape, forming what is called the *blade* Bl. On the inner side of the blade is the *fluke* P, (also called the *palm,*) a broad, flat, triangular plate tapered to a point for entering the soil, and by its broad surface taking a firmer hold of the ground. In large anchors the arm is straight from the crown C to the *bill* B or point of the fluke, but in small anchors the internal surface is curved. The whole length of the arm is nearly half the length of the round part of the shank, and tapers slightly from the throat to the blade. The stock of the anchor is sometimes formed of two beams of oak embracing the square, and firmly united by iron bolts and hoops. The stock is rather longer than the shank, and its thickness in the middle is about one-twelfth of the length; but it tapers to about half this, the tapering being on the under surface, the upper surface being quite straight. The stock is now often made of wrought-iron, passing through the hole in the square, and retained in its place by a swelling on one side, and a key passing through a hole in the stock on the other side.

It will be seen from this construction that when the anchor is let go the weight of the arms draws the anchor downwards, and keeps it in a vertical position, and the stock moves through the water with much less resistance in the direction of its length than it would do in any other direction. The heaviest end or the crown C first strikes the ground, and then the position of the stock at right angles to the arms, its length and height above the crown, together with the weight of the cable, are sure to make the anchor *cant* or turn over with one of the pointed arms on the ground, and this effect is greatly assisted by making the anchor descend quickly, in doing which the cable is arranged in regular coils on deck, one end being attached to the anchor, and the other made fast on deck. When the word "let go" is given the fastenings are cast off, and the anchor descends, drawing the cable after it with such rapidity that it is often necessary to throw water on the hause-holes to prevent ignition.

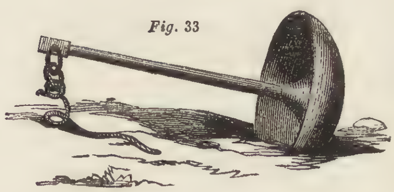
In pulling up, or *weighing* the anchor, a heavy purchase is required, for which purpose the cable is wound round a windlass, worked by a number of hands. In doing this, the ship is gradually drawn nearly vertically over the anchor, and its shank acts as a lever for starting it out of its place, the cable drawing up the shank, and turning the whole round on the point of the fluke. The holding power of an anchor is directly as its weight; but the power of holding increases as it penetrates the ground, and keeps out water from above. The seamen seem to be aware of this, for when they swing off from the end of their handspikes, they sing out, "Heave! heave together! heave hard!—heave, and water his hole!"—that is, only raise the shank so that water may get down to the arm of the anchor, and relieve it of the superincumbent pressure.

Respecting the dimensions of anchors, there is a rough rule in the navy to allow 1 cwt. to every gun: thus an 80-gun ship will have an anchor of 80 cwt. In merchant vessels the weight of the anchors is reckoned by the tonnage: thus a merchantman of 200 tons having an anchor of 10 cwt., 5 cwt. is afterwards added for every 100 tons; so that 300 tons would give 15 cwt., and so on. The dimensions are also estimated in the navy by calling the shank 10, the arm about 3, the breadth and depth of the palm about half this, the thickness or depth at the small round .42, at the throat .6, which are nearly the dimensions of the arms also, and the breadths about $\frac{4}{5}$ths of these, the edges being rounded. The weight of an anchor 10 feet in length is about 11.4 cwt.; and, supposing all the forms of anchor to be the same, the weights would be as the cubes of the length: hence the weight of an anchor can be found by multiplying the cube of its length by .0114. This generally gives a sufficiently close approximation; but for large anchors the result is too small, because the thickness is greater in proportion. The weight of an anchor includes that of the ring. An anchor of 94 cwt. has the following dimensions:—Length of the shank, about 19 feet; of the square end to which the stock is attached, above 3 feet; the thickness of the shank varies from 8 to 12 inches; each arm is more than 6 feet in length, and the triangular fluke measures 3 feet on each side; the ring is 3 feet in diameter, and made of iron 5 inches in thickness; the stock is about the length of the shank. The cost of such an anchor would be about 300*l.*, estimating the labour at about 3*l.* per cwt., and the iron at 9*s.* 9*d.* per cwt. For anchors of 10 cwt. and under, the cost of labour is about 24*s.* per cwt.

Boats and small vessels use a form of anchor called

Fig. 32.

Fig. 33



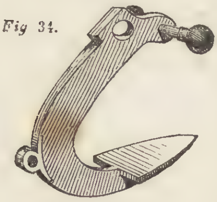
a *grapnel*, Fig. 32, consisting of five or six hooks ranged in a circle. A modification of this is the

(1) On the introduction of chain cables it became necessary to improve the strength of anchors, if possible without increasing their weight. This led to sundry changes of shape, and new proportions of the metal in the different parts; among other changes the shank was shortened, and the arms were strengthened.

mushroom anchor, Fig. 33, used in the East Indies. In this form no stock is wanted, as it is sure to attach itself to the bottom, in whatever direction it descends.

Anchors have also been formed with only one arm, as in Mr. Stuard's anchor, Fig. 34, patented some years ago. To ensure the falling of this anchor the right way, with the fluke down, the shank is made very short, so that, when suspended by the cable, it will cant the most, and when it has hold in the ground the ship will ride more safely; "as a long shank," says the patentee, "is more likely to be bent, or broken from its hold." For the sake of strength, the bars that compose the separate parts are put together in one length, so that there is no weld or joining in the whole length of the shank and arm. The hole at the top is to receive the ring for the cable; another hole near it is for the stock, which is a wrought-iron bolt, covered with cast-iron at its ends. The palm is made entirely of cast-iron, or a cast-iron shell filled with lead, which is a much heavier metal than iron. A small shackle is fixed on the bend of the shank and arm, for attaching the buoy-rope.

Fig 34.



Mr. Kingston has contrived an anchor of bell-metal, and in place of fastening the cable to a ring, it is made to pass through the centre of the shank, and is secured upon the crown by a knot of greater diameter than the tube through which it is brought.

But, perhaps, the greatest improver of anchors, of late years, is Lieutenant Rodger, who has patented two single-armed compound anchors, and a third, which has two arms. In the first, a piece of oak, saul, or teak, of the length of the anchor shank, and of proportionate thickness, is inclosed, above and below, by strong flat bars of iron, somewhat thicker towards the further end, where, at each side, a piece of iron is welded to them at the angle usual for the arms of the anchor, to bear the shank, and across the lower ends of these two latter pieces the palms of the anchor, of the common form, are also welded. At the other end of the shank, an aperture is left between the two flat bars that inclose the wooden case of the shank for the reception of the stock, which is properly rivetted and screwed firmly. Above the stock, an eye, or loop of iron is welded to the upper bar of the shank, through which a shackle passes for connecting the chain cable with the anchor, or holds a large ring for the reception of a hemp cable. This loop projects considerably from the side of the shank opposite to the palm of the anchor, in order that, when it is let go, the palm may be turned more effectually downwards, in the direction best calculated for entering the ground, by the resistance of the cable at the opposite side; and for this purpose, also, the shank is made to project some distance beyond the crown of the anchor, so as to turn the palm downwards, should the projection of the crown first come in contact with the ground.

To secure the wooden core within the flat bars of the shank, several bolts are passed through them, and the heads countersunk in one of the bars, while nuts or screws at their other ends press against the other bar. Short bolts are also fixed through the core, so as just to lie even with its sides, to prevent the looseness of the connexions, and the flat bars from approaching each other, in case the wood should decay, or be destroyed by worms.

The face of the stock farthest from the arms at each side of the shank, and the edge of the piece of iron bolted to it, are sloped so as to form an angle with the lower side more acute than the others, which when the fluke enters soft ground, causes the stock to bury itself downwards, and increase the resistance. A ring or loop is fastened to the top of the crown, for the reception of a buoy-rope, and another one is also fixed at the upper edge of the palm, in the space between the two parallel arms, through which a chain is to be passed for fishing the anchor.

In the second species of anchor, the flat plates that inclose the core of the shank are placed at the sides, instead of being fixed above and below it, as in the anchor just described. These are welded to the arms that proceed to the single palm, and are connected to each other by bolts passing through them and the core.

The third anchor (Figs. 35 and 36) has two palms

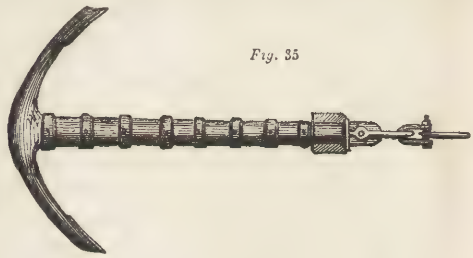


Fig. 35

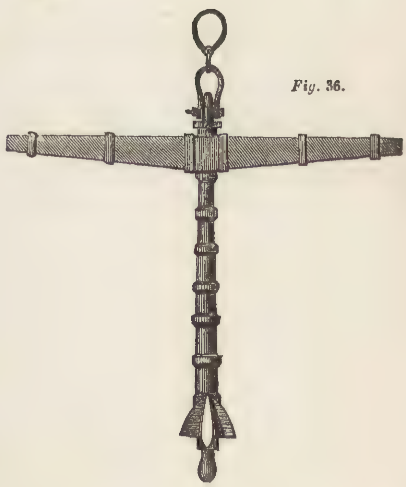


Fig. 36.

and two arms, but its shank has a wooden core inclosed, like the first, by stout flat bars, above and below, that bend off at one of its ends in contrary directions to form the arms, and to their extremities palms with flukes are welded. To strengthen these arms, a strong piece of the same curvature passes over their backs and the crown, and is welded at each

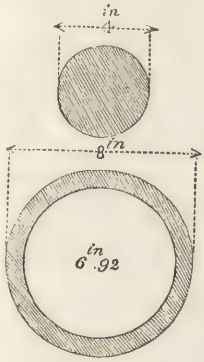
end to the palms and to the arms, and is further secured to the latter by transverse bolts. The wooden core of the shank is inclosed as before, and is also joined to the piece at the back of the arms by a strong iron band passing round the arms.

In some experiments which were made on the strength of this anchor, compared with three others of the ordinary construction, the first of the three was destroyed by a pressure of 33 times its own weight; the second by $34\frac{1}{2}$ times; the third by $28\frac{1}{2}$ times; and the fourth, which was Rodgers's, by $52\frac{1}{2}$ times.

Among the various professional opinions which have been taken respecting the merits of this anchor, that of Mr. Seaward is so full and satisfactory, that we quote it, with some few abridgements, for the information of the reader, as a specimen testimonial, in which praise is given, together with the reasons on which it is founded.

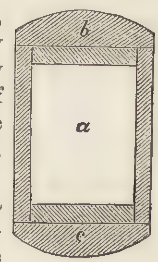
"It appears that the important distinctive feature of the patent anchor is the adopting of a hollow shank instead of the usual solid one, by which it is expected, that, with a much less weight of material, an equally strong anchor will be produced. There is no question that hollow bodies of the same weight, of similar form, and of equal strength of material, and goodness of parts, must be much stronger than solid bodies. Animal bones, and many other objects in nature, are sufficient proof of this fact. Indeed, it is demonstrable that the strength of similarly-shaped bodies to resist a transverse strain is as the sectional area of the body, multiplied into the depth of the body in the direction of the strain. Thus, comparing a solid cylindrical bar of iron, 4 inches diameter, (Fig. 37,) with a hollow cylindrical bar or pipe, 8 inches diameter, (the hollow cavity of the latter being also cylindrical, and 6.92 inches diameter, the metal being rather more than an inch thick all round,) it is clear that the sectional area of the metal in the two bars will be the same; but the capacity to resist a transverse strain in the two bars will be very different; the hollow bar will be twice as strong as the other, it being double the diameter.

Fig. 37.



"The shank of an anchor appears to be exposed to two different kinds of strain: first, that of the direct pull, or tension, and secondly, that of the transverse strain, or leverage. As regards the direct pull, the hollow shank possesses no advantage over the common shank; but, as regards the transverse strain, or leverage, which is probably by far the more dangerous strain to which an anchor can be exposed, the hollow shank, with the same weight of material, must be stronger than the solid shank, in the ratio of their respective sections in the direction of the strain. But there is one express condition, that all the parts of the hollow shank shall be equally well made, and equally well united together, as those of the solid shank. The hollow shank of the patent anchor is composed of three separate pieces, as shown in the accompanying transverse section. The centre piece *a*, Fig. 38, is a square pipe or box, with two solid cheeks, *b* and *c*, placed one at the top and the other at the bottom, the three pieces being then firmly united or connected together by means of a sufficient number of strong bands or hoops. The square pipe or box is formed by four plates, disposed as shown in the section; and the cavity is filled up by a piece of hard wood, which is employed to keep the plates of the box from springing out of their proper position.

Fig 38.



"If two four-inch square bars (Fig 39) be placed one on the other to support a weight, they will not be half so strong as a single bar, 8 inches by 4 inches, placed in the same position, because, taking the sectional area of the two bars, multiplied into their respective depths, it will amount to only 128; whereas, the sectional area of the single bar, multiplied into its depth, will be 256, twice the former; therefore the latter will be twice as strong. It is true that the two bars may be so firmly bound together, by hoops or otherwise, that the touching surfaces *a b* shall not move or slide in the smallest degree; in which case the two bars will have nearly all the stability of the single bar. On the latter principle, provided the hoops on the hollow shank prevent all motion or sliding of the surfaces, I see no reason why the shank made in three or more pieces, as described, should not be as strong as if made in one piece; but then it should be observed that an immense deal will depend upon the goodness of these hoops. I observe, however, that each end of the square box or pipe is formed solid, as shown in the longitudinal section (Fig. 40), the solid parts being firmly welded together. Moreover, these solid ends of the square box are also firmly united by welding with respective ends of the two cheeks; so that, in fact, the crown of this anchor, as also the upper end of the shank, is quite as solidly formed as in the common anchors. The hollow part of the shank reaches only from where the parts are bound together by the hoops. This is a most important advantage, and does more than anything else for the stability of the shank, by preventing the sliding of the surfaces. This, with the assistance of the hoops, renders the shank nearly as strong as if forged all in

Fig. 39.

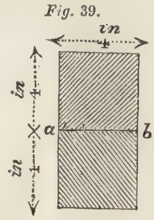
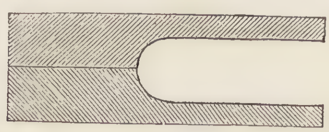


Fig. 40.



one piece, and probably stronger, from the facility of forging the parts in pieces of smaller bulk. Upon the whole, I have no hesitation in saying that an anchor with a hollow shank, made upon this plan, provided the work be well and properly executed, must be, taking weight for weight, considerably stronger than an anchor made in the common manner." [1]

In addition to the forms of anchor already noticed we must mention the *mooring anchor*, which is used for securing vessels in certain situations in harbours or roadsteads. These anchors are fixtures in the harbour, and their shape is of little consequence, compared with their powers of resistance. A mooring anchor is in some cases only a ponderous mass of stone, with a ring attached to the upper surface. In other cases, one of the largest ship's anchors, weighing 80 cwt., which has been accidentally damaged, is used, and one of the arms is beaten down upon the shank, to prevent it from entangling the cable. Hemmans' mooring anchor is of cast-iron, and very massive. The form somewhat resembles a spade, and when the edge has once penetrated the anchorage, it retains a very firm hold. Mooring anchors have a very strong iron chain, one end of which is attached to the ring, and the other supported at the surface by means of a buoy, and to which the ship is fastened.

Anchors are sometimes liable to be disturbed by a curious circumstance, namely, the formation of *ground ice*, as it is called, at the bottom of the water. The following are examples of this kind. On the 9th February, 1806, during a strong north-east wind, and a temperature of 34° Fahr., a long iron cable, to which the buoys of the fair way were fastened, and which had been lost sight of at Schappelswreck in the Baltic, in a depth of from 15 to 18 feet, suddenly appeared at the surface of the water, and floated there: it was completely incrusted with ice, to the thickness of several feet. Stones, also, of from 3 to 6 lbs. weight, rose to the surface, surrounded with a thick coat of ice. A cable $3\frac{1}{2}$ inches thick, and about 30 fathoms long, which had been lost the preceding summer, in a depth of 30 feet, appeared at the surface, with a coating of 2 feet of ice. On the same day it was necessary to warp the government ship into harbour, in the face of an east wind; the anchor, after it had rested an hour at the bottom, became so incrusted with ice that it required no more than half the usual power to heave it up. Had it remained sufficiently long, and the ice accumulated upon it to a greater thickness, the probability is that it would have risen to the surface.[2]

ANCHOVY. A family of small, soft-finned fishes, related to the herring, and inhabiting principally the tropical seas of India and America. There are six or seven species, of which one (*Engraulis encrasicholus*), common in the seas of Europe, is remarkable for its fine flavour; and a second, often met with in the same localities, is occasionally sold for the same purpose, namely, to form the celebrated anchovy sauce, known since the time of the Romans, and greatly esteemed by that people under the name of *garum*. The fishing-grounds for the anchovy are the shores of the Mediterranean Sea, where this fish occurs in prodigious numbers during the months of May, June, and July, migrating thither from the Atlantic for the purpose of depositing spawn. The fishing is carried on by night, the anchovies being attracted towards the boats by means of charcoal fires kindled in the sterns. When caught, the heads, gills, and entrails are removed, and the bodies salted and arranged in small casks, of from five to twenty pounds' weight. In this state they will keep for a considerable time, supposing that proper means have been taken to keep out the air. On opening the barrel, the fish should be plump and firm, with a silvery lustre on the skin, red flesh, and a small, compact form. If this be not the case, and the fish be flabby and pale-coloured, and tapering very much towards the tail, it will probably turn out to be not the true anchovy, but another species (*E. meletta*), inferior to it in quality. Anchovy sauce is made by bruising or chopping the fish, and allowing it to simmer with melted butter over a slow fire. A little vinegar and flour are frequently added, the one to give piquancy, the other to thicken the sauce, and in this way the fish entirely dissolves, and becomes of the proper consistence for use. It is then potted or bottled, and forms the well-known condiment so much in use. Anchovies sometimes appear at the breakfast-table, whole, and are eaten with no other preparation than that which they originally received to fit them for the market. Anchovies form an important article of commerce. About 120,000 lbs. are annually entered for home consumption.

ANEMOMETER, a wind-measurer, from ἄνεμος, the wind, and μέτρον, a measure. It is a matter of considerable importance to mechanical science to determine the velocity or force of the wind. Its direction is indicated by that ancient instrument the weather-cock, which consists of a vane of thin metal (formerly made in the shape of a cock, whence the name), and an arrow, turning freely at the upper extremity of a fixed vertical rod, the vane being on one side and the arrow on the other, so that the vane takes a position in the direction of the wind, and the arrow points to the quarter from which it blows. The first instrument invented for measuring the force of the wind seems to have been by Dr. Croune in 1667, which did not answer the purpose intended. Better instruments were invented by Wolfius, and other scientific men during the last century, but as their most valuable features have been preserved in modern instruments about to be described, it is not necessary to notice them here further than to state, that in most of these contrivances the velocity of the wind was measured by its mechanical effects. The compression of a spiral spring, the elevation of a weight round a centre acting at the arm of a variable lever, were the chief means employed to balance and consequently to measure the force of the wind. The

(1) Repertory of Patent Inventions, Vol. X. 1830.
(2) Arago. Annuaire pour l'an 1833.

spring, however, which from its simplicity has been commonly used, is liable to this objection, that it diminishes in elasticity by frequent compression, and thus the scale by which its force is ascertained must be constantly varying. To remedy this defect there has sometimes been substituted for the spring, a bag of air communicating with a glass tube in the form of a lengthened U, containing a liquid which is depressed in one leg and raised in the other in proportion to the compression of the air in the bag, thus affording a measure of the compressing force. Leslie's anemometer depended on the principle that the cooling power of a stream of air is equal to its velocity. Another instrument depended on the evaporation of water, the quantity evaporated in a given time being proportional to the velocity of the wind. The raising of a column of fluid above the general level of its surface is the principle of Dr. Lind's anemometer, *Fig.* 41. It consists of two glass tubes about 9 inches long and $\frac{4}{10}$ths of an inch in diameter, connected at their lower extremities by another tube of glass only $\frac{1}{10}$th of an inch in diameter. To the upper extremity of one tube is fitted a thin metal cap bent at right angles, so that its mouth may receive the current of air in a horizontal direction. Water is poured in at the mouth till the tubes are nearly half full, and a scale of inches and parts of an inch is placed between the tubes. When the wind blows in at the mouth of the cap, the column of water is depressed in the tube below the cap, and elevated to a similar extent in the other tube, so that the distance between the surfaces of the fluid in each tube is the length of a column of water, the weight of which is equal to the force of the wind upon a surface equal to the base of the column of fluid. The object of the small tube which connects the two larger ones is to prevent the oscillation of the fluid by irregular blasts of wind. The absolute velocity of the wind is deduced from the height of the column of water, or it may be ascertained from the tables constructed for the purpose. Thus, according to Dr. Lind, a column of water 0.025 inch, or a fortieth of an inch high, exerts a pressure of rather more than 2 ounces 1 drachm upon a square foot of surface, and balances the effect of a gentle wind moving at the rate of about $5\frac{1}{2}$ feet in a second, or not quite 4 miles an hour. When the column of water is 1 inch high, the force of the wind on a square foot is nearly $5\frac{1}{4}$lbs., its velocity $32\frac{1}{2}$ miles an hour, and its character a high wind. When the column marks 3 inches, the force is upwards of $15\frac{1}{2}$lbs. on the square foot, the velocity above $56\frac{1}{4}$ miles per hour, and the character a storm. At 9 inches the force on the square foot is stated to be 46lbs. 14 oz.; the velocity $97\frac{1}{2}$ miles an hour, producing a most violent hurricane. Thus, it will be observed that in the greatest storms, the difference between the atmospheric pressures on the windward and leeward sides of any object does not amount to $\frac{1}{50}$th of the pressure of the leeward side; for that is capable of supporting a column of about 33 feet of water.

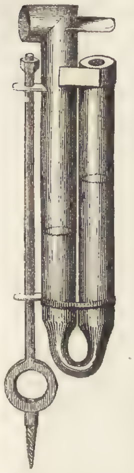
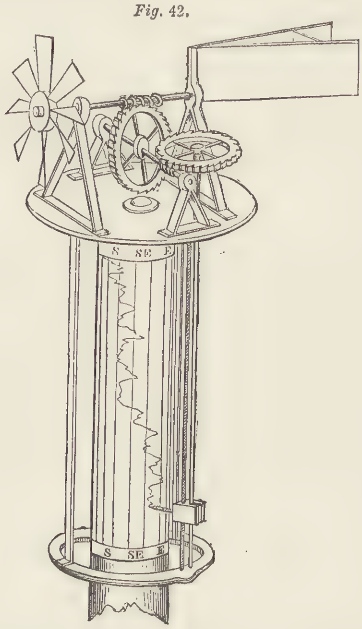


Fig. 41.

Of late years the most common forms of anemometer are those by Dr. Whewell and Mr. Osler. The general arrangement of Whewell's anemometer will be understood from *Fig.* 42, in which it will be

Fig. 42.



seen that by means of a vane, a windmill fly is constantly presented to the wind in whatever direction it may blow, and the fly of course revolves with greater or less rapidity according to the velocity of the current. An intermediate train of wheels, set in motion by the fly, causes a pencil to descend over a fixed cylinder, having thereon a trace of variable length, according as the wind is more or less strong. 10,000 revolutions of the fly cause the pencil to descend only $\frac{1}{20}$ of an inch. The surface of the fixed cylinder is japanned white, and is divided into 16 or 32 equal parts by means of vertical lines, the intervening spaces corresponding to 16 or 32 points of the compass, and a mark left by the pencil upon one or more of these spaces, shows the direction of the wind. The pencil has two motions, the first from above downwards, and this increases in rapidity as the wind blows more strongly, and by the extent of its depression registers the whole amount of wind that has been blowing. The second motion depends on the changes in the direction of the wind; and the pencil and its frame being carried round by the vane, the direction is registered by this cross movement. In this arrangement, therefore, the vane, the windmill fly, the intermediate train of wheels and the pencil, all obey the direction of the wind; while the cylinder which marks the points of the compass remains fixed, so that the pencil in descending and moving about with the wind thus traces an irregular line on the cylinder. If the fly revolve in the simple proportion

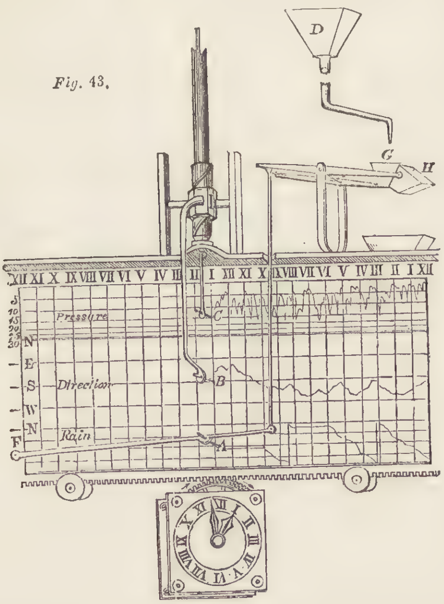
of the velocity of the wind, the length of line marked by the pencil is proportional to the space which would be described by a particle of air in a given direction in a given time, such as one day, taking into account the strength of the wind and the time for which it blows.

The line marked by the pencil upon the cylinder is not a single line, but a broad irregular path. This is occasioned by the wavering of the wind. The vane is in almost constant motion, swinging to and fro through an arc often not less than a quarter of a circle; but the middle of the line which gives the mean direction can readily be ascertained, while the length of the line is in proportion to the product of the velocity of the wind and the length of time during which it blows in each direction, which product is called its *integral force*.

The amount of friction in this machine is very considerable, arising from perpetual screws working in toothed wheels, for the purpose of converting the rapid motion of the fly into a slow, descending, vertical motion, again carried out by a thread turning within a movable nut. There is also the friction of the pencil attached to this nut pressing with sufficient force so as to leave a trace on the fixed cylinder. Hence when the force of the wind is small the fly would experience a greater amount of comparative retardation than with strong gales.

Osler's anemometer traces the direction of the wind and its pressure on a given area, together with the amount of rain, on a register divided into 24

Fig. 43.

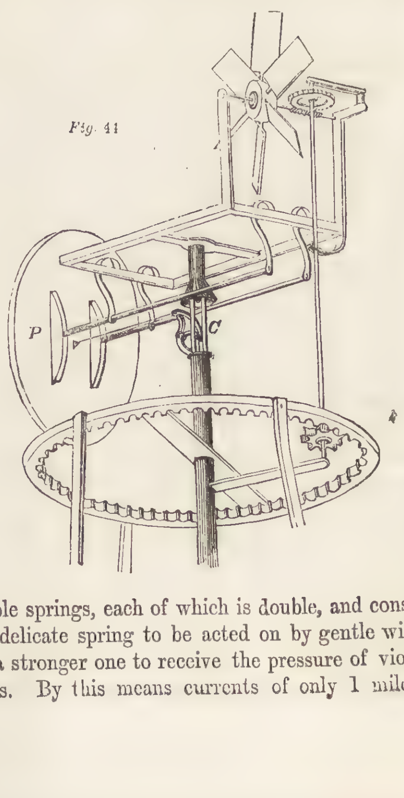


portions, corresponding to the 24 hours of the day. A portion of one of these register papers is shown in Fig. 43, the central part of which is marked with a series of lines corresponding to the cardinal points of the compass. This is for indicating the direction of the wind. The upper portion of the paper registers the pressure, and is graduated by a series of lines corresponding to the pressure in pounds on the square foot. The lower portion of the paper registers the quantity of rain. The whole length of the paper is divided, for the hours of the day, into 24 parts by lines crossing the former at right angles. A new register paper is placed on a board, and accurately set every day, and the board is carried along by means of a clock mechanism, behind three pencils A, B, C, which may be considered as the fingers or indexes of the machine. The board, which is placed upright as in the figure, moves on friction-rollers, and is thus moved along as the time advances.

The pencil B is the index of direction. The method by which the instrument is turned so as to obey the direction of the wind will be seen in Fig. 44. A set of vanes or sails revolve vertically in a plane at right angles to that of the pressure plate P, and drive a cog-wheel, which by rolling on a fixed cogged circle, turns all the rest of the apparatus round till the vanes are presented edgewise to the current, so as not to be turned by it either way, when the pressure plate being at right angles to the vanes is acted on with full effect. As the vanes turn in the direction of the wind, a spiral worm on the shaft near its lower end raises or lowers the nut I, Fig. 43, which does not turn round, and from which hangs the arm carrying the middle pencil B, which thus traces a mark on one of the long lines of the register if the wind be blowing towards one of the cardinal points, or a mark between these lines, if it be blowing from intermediate points, such as NN.W., N.W. &c., which may be represented by fainter lines parallel with the others.

The method by which the pressure plate P, Fig. 44, is always made to face the wind, has been already described. This plate is suspended by means of 4

Fig. 44



flexible springs, each of which is double, and consists of a delicate spring to be acted on by gentle winds, and a stronger one to receive the pressure of violent winds. By this means currents of only 1 mile an

hour are measured, and the pressure of the wind in violent gales also recorded. The motion of the plate is communicated to the register below by a wire connected with the bell-crank C, with another wire descending through the hollow upright shaft and kept stretched by a spiral spring. To this wire is attached the upper pencil C, which thus descends lower the more the pressure plate P is pushed back, and returns to the top of the paper when the pressure ceases. The distance to which the pencil is thus depressed, represents, by means of a scale of parallel lines, shown in Fig. 43, the pressure of the wind in pounds on the area of 1 square foot, or its velocity in miles per hour.

The pencil A registers the rain in a similar manner. The rain after falling into the vessel D on the roof flows into G, one of the two divisions of a gauge balanced on an axis and supported by a second balance.* As the water accumulates, this second balance begins to descend, and so raises the upright rod to which the lever F A is attached. This lever F A carries the pencil, which by this action is raised, showing upon the lowest set of parallel lines the quantity of water collected in the gauge. When this quantity becomes equal to a certain depth of rain or to a certain number of cubic inches on a foot square, the small gauge oversets, the water is discharged, and the other compartment H of the gauge is brought under the pipe. The pencil then returns to its first position at the bottom of the paper, and begins to rise on the scale as the rain is collected. In a trace of this kind it will be seen that the more rapidly the rain falls, the sharper will be the angles formed by the trace of the pencil; but if the rain be slow and gradual, the elevating or diagonal lines will be drawn out into a considerable length; and when no rain falls a horizontal line will be drawn, as shown in Fig. 43, from VI to ¼ after VIII, and from X ½ to I.

It will be seen, then, from this arrangement, that as the register is constantly and hourly moved along behind the three pencils, a continued record or trace of the direction and pressure of the wind, together with the amount of rain, is left on the paper. Figs. 43 and 44 are intended to convey a general idea of Mr. Osler's arrangement in the Royal Exchange, London, where the register paper is made to last a week. When the Editor visited the Meteorological Observatory at Greenwich a few years ago, he noticed that the register was placed horizontally on a table, and being on a larger scale, it was changed every day.

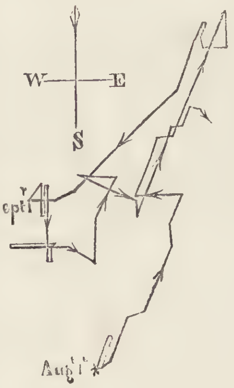
* By means of such an instrument we ascertain the *direction*, the *duration*, and the *force* of the wind. It is necessary, however, for the purposes of science that the *integral* of the wind be deduced for each point of the compass; that is, to ascertain the entire quantity of wind which has blown from each point during a given period. Now if the force of the wind were constant, the integral would be obtained by multiplying the length of time that the wind is blowing, by the velocity with which it moves.

The integral of the wind, or the total quantity as measured by its intensity and duration jointly, may be thus illustrated. If the intensity or force of one wind be to that of another as 2 to 3, and if the former wind last 6 hours, and the latter only 2, the integral of the former is double that of the latter, for it has blown twice as much air over the place; for supposing the second wind to be opposite to the first, it must blow for 4 hours before it will carry back all the air which the first had blown over. The integral, therefore, is proportional to the product of the mean intensity, or velocity, and the duration multiplied together.

In a similar manner the area of a rectangle is proportional to its length and breadth taken jointly. Now if we have such a figure whose length represents the *duration* of the wind, while its breadth represents the *force* or *velocity*, as this force is constantly varying, the breadth of the figure must also vary, in order that its area may still represent the *integral* of the wind correctly. It is the object of Osler's anemometer to describe such a figure. In Whewell's instrument, on the contrary, the integral is represented simply by the depth which the pencil descends. In this instrument no attempt is made to record the *time* during which each wind blows, the *times of its changes*, or its *force* at any given moment, but merely the order of its changes of direction, and the integral or entire quantity that blows from each point, or rather from each rhumb or division of 11¼ or 22½ degrees. This is known by the length of pencil trace described in each vertical division of the cylinder measured vertically, not following the windings of the track. These windings must be neglected as far as they are confined to one rhumb or division, the centre of which corresponds to one of the 16 or 32 points of the compass. All winds therefore not deviating more than 5⅝° from any one of these points if 32 be used, or 11¼° if 16 be used, are regarded as blowing exactly from that point. This is a defect common to all anemometers now in use, but by increasing the number of subdivisions, the results will be more accurate.

Having obtained by means of Whewell's instrument the integrals, or lengths of line described by the pencil in each division during a certain period, we may lay down these lengths, or proportionate ones, in their proper order and direction, so as to form a continued crooked line, which expresses all the quantities and changes of the wind, and is called the *type* of the wind for that particular place and period. Fig. 45 represents the type of all the wind that blew over Plymouth during the month of August and part of September, 1843. Such a line may be regarded as the path that would have been described by a vessel drifting upon a still lake during that period,

Fig. 45.



provided it moved with a speed always bearing a constant ratio to that of the wind. If the two ends of this line be joined by a straight line, this will show the direction of the *resultant*, or average effect of all the winds felt at Plymouth during that period; which in this case is N. 23° E., or about equivalent to a SS.W. wind. This average direction is not the *prevailing* direction of the wind, or that in which it most commonly blows; for the prevailing winds may be very gentle, and the greater force of those from the opposite quarter may more than compensate for their shorter duration, so that the average direction as regards the integral, or time and intensity taken jointly, may be very different, or even opposite to the average direction if time alone be considered. In this country, however, both these averages have nearly the same direction; the latter, or time-average, being equivalent to a wind blowing from some point between S. and W.; and the former, or true average, though apparently very variable when the resultants of different months or seasons are compared, yet in the type of a whole year, its general direction is found invariably to run northward, and mostly eastward from the starting point. In the present state of the inquiry there is some discrepancy between the results obtained by different instruments; Whewell's placing the mean direction for three years nearer N. than E., while Osler's makes it nearer E. than N. The latter is more likely to be correct, because in Whewell's instrument the velocity of the windmill fly does not bear a constant ratio to that of the wind, but is more than proportionally faster in a quick than in a slow wind, so that the distance which the pencil descends being proportional to the revolutions of the fly, cannot correctly represent integrals of wind; that is to say, the spaces through which it descends during two successive periods do not necessarily bear the same ratio to each other, as do the quantities of wind that have passed over the instrument during these two periods. This objection is surmounted in Osler's instrument, which is driven by a clock, and merely directed or regulated by the wind.

But if Osler's instrument is more correct than Whewell's, it is more difficult to represent the results in the useful form above described. If the instrument be in perfect order, the upper trace made on the paper by the pencil C should be such that its ordinates[1] are proportional to the velocity of the wind; that is, the ordinates at any two different moments should bear the same ratio to each other, as did the velocities of the wind at these two moments. In this case the total amounts of wind passing over the instrument during different periods, will be proportional to the areas of the portions of curve traced during those periods; that is to say, the spaces contained between the curve, the base line, and the two ordinates at the beginning and end of each period. It is only by measuring and comparing these areas that we can obtain the proportion of the integrals of wind during different periods of time.

To lay down a type of the wind similar to Fig. 45, we must divide the periods in such a manner, that during each period in which the direction of the wind may have been constant, or confined within certain limits, such as two rhumbs, or $22\frac{1}{2}°$, or one rhumb, $11\frac{1}{4}°$. For this purpose that part of the register paper which registers *direction* must be divided by 16 or 32 longitudinal lines, such that when the vane points to any one of the 16 or 32 principal points of the horizon, the pencil B may rest midway between two of these lines. We must then note all the points where the pencil track intersects these lines, and from every such intersection raise a perpendicular to the top of the paper; these perpendiculars will evidently divide the upper curve, or that of force, into portions, each of which may be regarded as belonging to one wind only, for during its description the wind did not deviate more than $5\frac{1}{8}°$, (if we use 32 points, or $11\frac{1}{4}°$, if we use only 16,) on either side of a certain point. By ascertaining the areas of these different portions, and drawing lengths of line proportional to those areas, placing those lines in their proper directions, and in their proper order, we may obtain a type of the wind more correctly than by the method before described.

The integrals of the wind have hitherto been referred to only as relative quantities, admitting of comparison only with each other. They have, however, absolute values easily comparable with our common standards or measures. If a pressure plate, acting on a spring, as in Osler's anemometer, be fixed to one extremity of a long beam, or some machine by which it could be moved through the air with any required velocity between 1 mile and 50 miles an hour, it matters not whether the path be straight or circular provided the plate always face the direction in which it moves. If the air be still, the effect on the plate is the same as if it were at rest, and received a wind of a known velocity upon its surface. By this means it can be discovered what velocity of wind is required to produce any amount of compression in the spring, such as may be obtained by placing weights of known value on the pressure plate. In this way a scale of the velocities or force of the wind may be constructed, and absolute values in miles may be assigned to all the lines which compose any type of the wind; and on measuring by the scale thus obtained, the length of the resultant or line joining the two ends of the type, we thus obtain not only the direction, but also the extent in miles of the entire movement of air produced by the combined effect of all the winds that have blown during the period for which the type was constructed. In this way it was ascertained that the resultant of all the winds that blew over Greenwich during the year 1841, was equivalent to the passage of 47,900 miles of air towards E. 28° 30′ N. In 1842 the direction of the resultant was E. 27° N., and its length 36,750 miles. By dividing these numbers by

(1) The ordinate of any point of the curve, is its least, or perpendicular distance from the axis, or base line, which in this case is the top of the paper.

the number of hours in a year, the total effect of the wind in 1841 is found to be equivalent to a constant current towards E. 28° 30′N., at the rate of 5.4 miles an hour; and in 1842 towards E. 27° N., at the rate of 4.2 miles an hour; or in other words, as if there had blown during these two years a constant wind from W. S. W. ½ S. at 4¾ miles an hour.

But the average velocity of the winds at Greenwich during the former year was 18.7, and during the latter, 18.3 miles an hour; for the whole integrals of wind for those years, as shown by the length of their type line, measured along all its windings, was in 1841 no less than 167,322 miles, and in 1842, 159,950 miles, showing that the whole movement of the air in this country is about 4 times as great as its resultant or effective movement. The more variable the wind may be at any place, the smaller the proportion of it that will be effective; and if these observations could be made on the open ocean within the range of the constant trade winds, the type would probably be a straight line, and the numbers expressing the total and resultant integrals of wind would be equal.

The direction or length of the resultant for any given period may be obtained more simply than by laying down such a type as Fig. 45, for as the lines, in whatever order they may be placed, will eventually lead to the same point, the figure may be simplified by collecting and summing up all the integrals that belong to the same wind or point of the compass, or that fall within the same angle of 11¼° or 22½°, but the smaller the angle the better, and then drawing lines proportional to the 16 or 32 sums thus obtained, which lines placed in any order, but in their proper directions, will give the same resultant as if the whole type were drawn. But as some of the lines thus drawn are parallel to others, it is not necessary to draw more than half of them, subtracting from

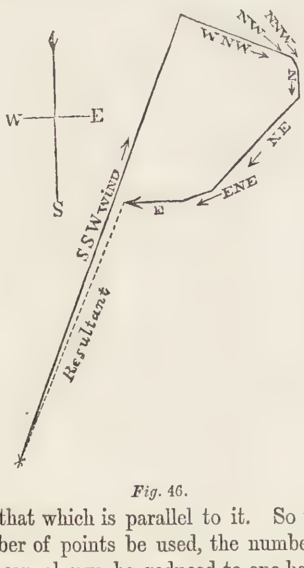


Fig. 46.

each one that which is parallel to it. So that whatever number of points be used, the number of their integrals can always be reduced to one-half, by subtracting each non-effective wind, or each one that is less than its opposite, from that opposite, the remainder being alone retained. Thus, Fig. 46 contains all the effective lines of Fig. 45 treated in this manner, and gives the same direction and length of resultant, by which means much labour is saved.

There are methods of finding the resultant by calculation, for which we must refer to other works, and especially to Sir W. Snow Harris's Report to the British Association in 1844, on the working of Whewell's and Osler's Anemometers at Plymouth in the years 1841, 1842, and 1843. The Editor has also to acknowledge the use he has made in this article of a small work of his, entitled "The Tempest," published in 1848, under the direction of the Committee of General Literature and Education, appointed by the Society for Promoting Christian Knowledge. The reader interested in the subject will do well to consult the Reports of the British Association, and also the Meteorological Reports of the Greenwich Observatory.

ANNEALING, (from an Anglo-Saxon word *Anælan*, to heat or to burn.) From the constant tendency of the English to abbreviate words in common use, this term has been contracted by workmen into *nealing*. Annealing is a process used in the manufacture of GLASS and also of certain metals. In the glass manufacture it consists in placing the articles of glass while hot in an oven called the *leer*, where they are allowed to cool gradually. They would otherwise be too brittle for use; for the slightest scratch is often sufficient to cause unannealed glass to break, and even to fly to powder, while it will often resist a considerable blow. The curious properties of unannealed glass can be exhibited by means of the *Bologna phial* and *Prince Rupert's drops*. The former is a rudely shaped phial 3 or 4 inches long, about an inch in diameter, and the glass is about ⅛ or $\frac{1}{10}$ of an inch thick. If we drop into this phial a pistol bullet from the height of 2 or 3 feet it will not break it, or we may strike it a hard blow on the outside with the handle of a hammer without producing fracture, but if a grain of sand or a sharp bit of flint be allowed to fall into it, it will crack and fall into fragments. This effect is in some cases produced immediately, but in other cases, several minutes elapse before it takes place: and when we think the experiment has failed and are about to drop in another bit of flint, it will suddenly fly to pieces. This remarkable property seems to be destroyed by age, for among some apparatus which has come into the possession of the Editor, are a number of Bologna phials at least 50 years old, some of which have lost this property; but some specimens which will not break by a particle of flint, fly to pieces on scratching the interior surface with a file. Fig. 47 is a copy, one half of the size of the original of one of these phials which have lost this property. It would seem that during the long period in

Fig. 47.

which it has been preserved in a warm room, a slow and gradual, but partial annealing has taken place.

Prince Rupert's drops are so called from their having been first brought to England by Prince Rupert, and exhibited before Charles I. in 1661. They are also called *lacrymæ virteæ* or glass tears. When melted glass is allowed to drop into water it forms a globular portion at one extremity, and gradually tapers into a small tail at the other. (Fig. 48.) The greater number burst in the water, but those which remain entire exhibit all the properties of unannealed glass in a high degree. They will bear a smart stroke on the thick end without breaking, but if a small piece be snapped off from the tail, the whole will burst into powder with a smart crack. Under the exhausted receiver of an air-pump they appear to explode with more violence than in the air, and the powder is finer. If the Bologna phial or these drops be cautiously heated and slowly cooled, these peculiar properties are lost.

Fig. 48.

There are a few substances in nature which increase in bulk in passing from the fluid to the solid state; water and glass are examples. When glass is allowed to cool slowly, its particles arrange themselves in such a way as to form a fibrous texture, producing an elastic substance, and one susceptible of long continued vibrations; but when a quantity of melted glass is suddenly cooled, the surface first crystallizes and forms a solid shell or coating round the interior fluid parts, thereby preventing them from expanding as they become solid. This causes them to be compressed together with little mutual cohesion. Thus in the Prince Rupert's drops it is evident to the eye that the inner substance is cracked and divided into a multitude of detached parts, held together by the smooth external coat. These internal particles tend to press outwards so as to occupy more space, but are prevented from doing so by this external coat. In consequence of this effort to expand, the greater number of glass drops burst in cooling; those which remain entire may have a thicker external coat than those which burst; they will bear a smart stroke upon them, because each drop on being struck vibrates as a whole, and does not transmit its vibrations from the exterior to the interior; but if the tail be broken off, a vibratory movement is communicated along the crystalline surface without reaching the internal parts; this allows them some expansion, and thus overcoming the cohesion of the thin outer shell, the glass is burst and dispersed in powder. In unannealed glass vessels, such as a drinking glass, the same thing occurs. If such a vessel be struck or thrown into vibration, the vibrations may continue for a considerable time before the internal parts overcome the resistance. If the vessel be thin, the regular crystallization of the surface may extend through the whole thickness, or the quantity of compressed matter in the middle may be so small as to be incapable of bursting the external crust. It often happens that a wine glass or other article of irregular form breaks in cooling, simply from its unequal contraction at different parts.

Some writers regard the external crust as a hollow arch enclosing a quantity of loose materials, and the effect of scratching this crust or breaking off a portion of it, to be the same as suddenly pulling out one of the voussoirs, whereby the whole system falls to pieces.

In the process of annealing, glass is kept during many hours in a state approaching the fluid; the heat increases the bulk of the outer or crystalline portions, and renders it so soft that the interior parts can expand and crystallize regularly. Mr. Pellatt has shown experimentally that a re-arrangement of particles does occur in annealing. Two pieces of the same length of tube, each 40 inches long, were the subject of trial. One piece that was sent through the leer, contracted $\frac{1}{16}$ of an inch more than the other which was cooled as in the open air. The Editor has also noticed that the fragments of a Bologna phial when put together do not fit, as the fragments of annealed glass do.

Lamp glasses, tubes for steam gages, and similar articles which are exposed to sudden transitions of heat and cold, may be more perfectly annealed than is done in the glass-house, by placing them in a vessel of cold water, and raising it slowly to the boiling temperature, and keeping the articles for some hours at that heat, and then allowing the whole to cool very slowly. Articles of flint-glass which have to be cut are, when found to be imperfectly annealed, subjected to this process, which is found preferable to passing them a second time through the leer. A lamp-glass is much less exposed to fracture after it has been once used, because the heat, if not too suddenly checked, completes the annealing.

The process of annealing is extensively employed for softening the malleable metals, which, under the action of the hammer or of the roller, have gradually increased in hardness and elasticity and in density from the close approximation of their particles. Steel often becomes remarkably hard and dense in the process of *hammer hardening*, or hardening without heat, which is frequently the only means of hardening some kinds of steel springs. In some descriptions of steel goods, which are formed by the hammer and then required to be filed into shape, as in scissors, or teeth to be cut as in files, the metal is softened by annealing. So also in the process of wire-drawing, the metal is greatly increased in hardness and elasticity, which if not removed from time to time by annealing, would prevent the extension of the wire, and render it too brittle to be applied to any useful purpose. In rolling or flattening metals, the working and annealing are alternately repeated until the sheet reaches its limit of tenuity. The brazier who forms vessels of copper and brass solely by the hammer, can work on them only for a short time before they require annealing.

Articles of iron and steel are sometimes annealed by piling them in an open fire, and raising them slowly to a red heat: they are then left to cool gradually. This method is injurious on account of a scale of

oxide which forms on the surface, thereby depriving the steel of a portion of its carbon, which confers the property of imparting a keen edge, so essential to cutting instruments. Articles of iron and steel ought to be annealed in close vessels, or in a trough or recess made of fire brick, and covered up with ashes or clean sand; or if a small vessel be employed, the cover may be of the same material as the vessel. The oven or trough is heated by the flame of a furnace passing under and round it until the whole is at a red heat. It is then allowed to cool without letting in the air. Goods thus treated become softer than by the common method, and the surfaces have a metallic whiteness imparted by the carbonaceous matter of the ashes. Annealed goods lose their brittle character so that they can be bent without breaking. The fracture before being annealed is smooth and short; after that process it is rough, and exhibits bright parts of a crystalline appearance. Copper and brass suffer less from being annealed in an open fire than iron and steel: but a close vessel is necessary in order to preserve their metallic lustre. Very small brass wire is sometimes annealed by holding it in the flame of burning hay and straw.

Soft metals, such as tin, lead, and zinc, after being hardened by hammering may be softened by the action of boiling water. Most of the hard metallic alloys when made red hot, suffer no great change whether they be suddenly quenched in water or not. Pure hammered iron after annealing becomes equally soft whether it be cooled suddenly or slowly; but some inferior kinds of iron become hard by immersion in water. Steel receives by sudden cooling that extreme degree of hardness, combined with tenacity, which adapts it beyond every other material for cutting tools, especially as it admits of being regularly graduated from extreme hardness to the softest state when subsequently heated or tempered. The following are a few examples of the method of treating steel, so as to produce extreme hardness, and ending with the reverse condition. A thin heated blade worked between a cold hammer and anvil, or other good conductors of heat, becomes perfectly hard. A thicker piece of steel cooled by exposure to the air on the anvil becomes rather hard, but not too hard to be filed. When it is placed on cold cinders, or other bad conductor of heat, it becomes softer; but it becomes softer still when placed in hot cinders, or within the fire, and allowed to cool, by gradual extinction. When the steel is encased in close vessels with charcoal powder, and raised to a red heat, and allowed to cool in the furnace, it assumes its softest state; unless, indeed, it be made to undergo partial decomposition by enclosing it in a close vessel with iron turnings or filings, or with the scale from the smith's anvil, or with lime or other matters which attract carbon from its surface; this reduces it to the state of pure soft iron. Some descriptions of cast-iron may be made as hard as the hardest steel, forming what are called *chilled iron castings.* The reverse process is annealing with partial decomposition; this forms what is called *malleable iron castings,* and the process is so successful that cast-iron nails may be clenched. The purest iron, and most varieties of cast-iron may be superficially converted into steel by a process called Case-hardening. For further particulars on this interesting subject we must refer to Hardening and Tempering.

The change which is produced by annealing is not well understood. Most of the malleable metals assume two distinct forms; one crystalline, which is the result of slow cooling, and the other fibrous, which is brought about by hammering or rolling. If hammered or rolled beyond a certain point, the metals become so hard that they cannot be bent without breaking. If annealed beyond a certain point the metals become crystalline. Thus, zinc may be drawn into a very flexible and tenacious wire, but if kept in boiling water too long it resumes its original brittleness, and displays a crystalline appearance when broken. The particles of the metal change their arrangement without altering the external form, and this change may be brought about in various ways; thus, brass wire loses its tenacity by exposure to the fumes of an acid, and even by air acting on its surface in a damp atmosphere. Hence it is necessary to preserve wire, such as is used in the manufacture of pins, in a dry air or under the surface of water.

ARNOTTO. Annotta, a red colouring matter obtained from a plant *(Bixa orellana),* Fig. 49,

Fig. 49.

common in the West Indies, where it is extensively cultivated on the banks of rivers, sometimes giving its name to the district, as *Annotta Bay,* on the northern coast of Jamaica. The arnotto plant is a small tree with deep-green, shining leaves, and clusters of purplish flowers. These are succeeded by bristly heart-shaped capsules, or seed-pods, containing numerous seeds covered with a soft, sticky rind of a bright red colour. It is a thick extract of this rind made into cakes and balls, which forms the arnotto of commerce. The cakes are usually of two or three pounds weight each, and are packed in casks with

large flag leaves, hence the term *flag arnotto.* A superior kind, called *roll arnotto,* is a harder and more concentrated extract, of which but little is imported. The colour obtained from fresh pods of the plant is much superior to that of either of these preparations, leading to the conclusion that the method of preparing them, which is by a high degree of heat and fermentation, is injurious to the colour.

Arnotto dissolves entirely in water or milk, and is much used in colouring cheese and butter in England and Holland, the colouring matter being diffused in the milk previous to the manufacture. The Spaniards employ this substance in colouring and flavouring their chocolate and soups, esteeming it wholesome and stomachic. Dyers obtain from it the reddish colour called *aurora.* The liquid sold under the name of *Nankin dye* is a solution of arnotto in potassa, and pure water. A solution is also made in alcohol, and used in varnishing and lacquering. The Indians paint their persons with a mixture of arnotto, gum, and lemon-juice, as a preservative against the attacks of insects. Arnotto also has a fabulous reputation of being an antidote to the poison of the cassava root, which has fatal properties when raw, although, when cooked, it is a wholesome food. The consumption of arnotto in Great Britain has greatly increased of late years. In 1820, it amounted to but little more than 50,000lbs.: three or four times that quantity is now imported. The botanical position of the arnotto plant, is in a small group of tropical plants, called bixads, now included by Lindley in the natural order *Flacourtiaceæ.*

ANTHRACITE, [See Coal.]

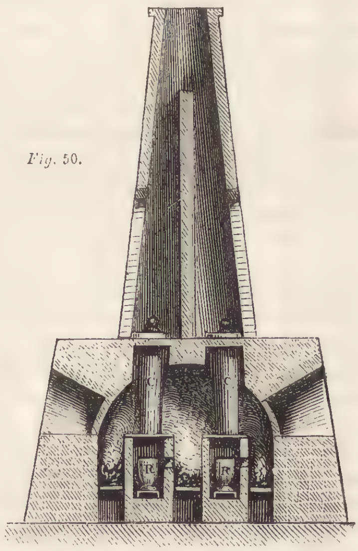
ANTIMONY is a metal discovered by Basil Valentine, a monk of Erfurth, and an alchemist of the fifteenth century. It is related that having thrown some of it to the hogs it purged them violently, after which they became fat; and thinking that his brother monks might derive benefit from a similar dose, he administered it; but the effects were fatal, for the monks died; hence the medicine was called *anti-moine* or anti-monk. The ancients appear to have been acquainted with some of the compounds of this metal,[1] which Pliny names *stibium,* a word still used to express the metal, or in chemical symbols Sb. Its equivalent is 129.

Metallic antimony has a distinct platy, crystalline structure, and by particular management may be obtained in crystals which are rhombohedral; this metal has a bluish white colour, and a strong lustre; it is very brittle, and can be easily reduced to powder. Its specific gravity is 6.8. It melts at a temperature just short of redness, and boils and passes off in vapour at a white heat. It has a peculiar taste and smell, especially in the state of vapour. Antimony is not oxidized by the air at common temperatures; but when strongly heated it burns with a white flame, producing an oxide which often forms beautiful crystals. If a globule of antimony melted at the blow-pipe be thrown upon a sheet of paper or a board, it sparkles and bursts into a number of small spheroids, which remain hot for a considerable time, and move about the paper leaving traces of oxide behind them. There are three compounds of antimony and oxygen, viz., the oxide, antimonious, and antimonic acids. These acids combine with bases forming salts, which are distinguished as *antimonites* and *antimoniates.*

Antimony is dissolved by hot hydrochloric acid with evolution of hydrogen, and the production of a chloride formerly called *butter of antimony,* a substance sometimes used with sulphate of copper for bronzing gun-barrels, the iron decomposing the chloride, and depositing a thin film of antimony on its surface. Nitric acid oxidizes antimony into antimonic acid. Sulphuric acid has scarcely any action on it.

Antimony is found in many parts of Europe, but the mines of this metal are not numerous; it occurs native in Sweden, in France, and in the Hartz; but its principal ore is the sulphuret, which occurs massive and crystallized. There are several varieties, of which the most common is the radiated. This is of a grey colour, brittle, and frequently crystallized in four and six-sided prisms. The sulphuret is associated with quartz, sulphate of baryta, and carbonate of lime, from which it is separated by fusion; a method of purification analogous to the mechanical preparation of other ores, but on account of the great fusibility of the sulphuret of antimony this separation is accomplished by means of heat. For this purpose the ore is placed in large crucibles, C C, (Fig. 50,) perforated with a number of small holes in

Fig. 50.



the bottom, and supported by tiles which are furnished with openings for admitting the perforated part of the crucibles. The fused matter is received into other crucibles, R R, placed in enclosed compartments. The upper crucibles are fitted with a

(1) The sulphuret was used by the ladies of Rome as a cosmetic for painting the eyebrows and the edges of the eyelids. The smoke-black of a kind of resin, or of the shells of almonds, is now used for the purpose by females in the East.

cover, which is luted on, and a lute is also applied to the junction with the lower vessels. Heat from wood fuel is then applied, and after some hours firing the stony portion of the ore is left in the top crucibles, while the bottom ones contain the sulphuret which is known in commerce as *crude antimony.* In some works a small circular furnace is used for heating the crucibles which contain the ore, and the recipients being placed on the outside, the fused sulphuret flows into them by a channel which connects the two together. By this means the furnace can be worked constantly, whereas by the former method the cooling of both crucibles occasions a waste of fuel. The arrangement will be understood from Fig. 51.

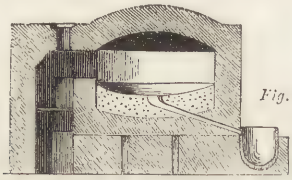


Fig. 51.

In the department of La Vendée, in France, this method is improved by heating the ore on the concave sole of a reverberatory furnace. This sole is formed of clay and charcoal, and communicates with a recipient outside by means of a channel, the upper extremity of which is stopped with ashes during the melting. The charge consists of 7 or 8 cwt. of the ore, and each tapping yields about 4 cwt. of crude antimony, which is about 50 per cent: in other places the yield is not more than from 30 to 40 per cent. Wood is the fuel employed.

When sulphuret of antimony is roasted in contact with the air, oxide of antimony is formed, which unites with that portion of the sulphuret which has not been decomposed. In this way several oxy-sulphurets are formed, which melt, and yield in cooling some brown vitreous substances, which are known in commerce as *glass of antimony, liver of antimony,* or *crocus.* Glass of antimony consists of 8 parts of oxide and 1 of sulphuret. It is transparent, and of a reddish yellow colour. Crocus contains 8 parts of oxide and 2 of sulphuret; it is opaque, and of a yellow-red colour. Liver of antimony is opaque, and of a deep brown colour; it consists of about 4 parts sulphuret and 8 parts oxide.

The reduction of the crude antimony to the metallic state is attended with some difficulty, for antimony is a metal sufficiently volatile to occasion great loss, but not volatile enough to pass over by distillation. The first process in the reduction is to roast the crude antimony at a very moderate heat, whereby, in 100 parts, 86 parts ought to be converted into protoxide, and the sulphur disengaged, to be converted into sulphurous acid; but in practice not more than about 60 or 65 parts of the protoxide are obtained. These 65 parts are next mixed with 8 or 10 parts of charcoal-powder, sprinkled with a strong solution of carbonate of soda. The mixture is placed in crucibles, and kept at a good red heat until the fusion is complete. By this process *regulus of antimony* is produced, while the scoriæ consist of a double sulphuret of antimony and sodium. The object of the carbonate of soda is to reduce a portion of the sulphuret of antimony by forming sulphuret of sodium, which combines with the remainder of the sulphuret of antimony in such a way as to cause it to collect in the scoriæ.

From the crucibles the metal is run into hot and greased moulds; but it is not as yet sufficiently pure to assume the crystalline form so much prized in commerce. It is remelted, with a portion of the scoriæ obtained in previous reductions, together with a certain proportion of the roasted mineral. The result of this second process is the production of an increased quantity of scoriæ and the purification of the metal.

Of the 65 parts of roasted sulphuret 45 parts of regulus are obtained in the first fusion, and this quantity is reduced to about 42 in the second; or, in other words, 100 parts of sulphuret of antimony, which ought to produce 73 of regulus, actually produce only 40 or 44. A portion is lost by volatilization, and another portion remains in the scoriæ. The scoriæ is known in commerce as *crocus* or *kermes,* and is used in veterinary medicine. It consists of sulphuret of antimony and alkaline sulphuret.

As iron combines readily with antimony, the sulphuret is sometimes reduced by heating it in contact with iron filings: as the iron tends to unite with the antimony, when in excess, an atom and a half of iron is employed to each atom of sulphuret of antimony, or 45 parts iron filings to 100 parts sulphuret of antimony.

M. Dumas states that many manufacturers keep their processes secret, which sufficiently accounts for the defective state of this branch of metallurgy; for, had they been thrown open to scientific chemists, they would have been investigated and improved.

In some smelting-houses there is a loss of regulus amounting to 33 per cent., and a much larger expenditure of fuel than is necessary. The secret consists in giving to the surface of the ingots a beautiful stellated appearance, which the alchemists formerly regarded as a mysterious guide to the secrets of transmutation, and which is now valued in commerce as an indication of superior purity in the metal. But it is well known that when pure antimony is cooled very slowly, in a still place, the crystallization is always very beautiful; and these conditions suffice to account for an appearance the importance of which is exaggerated by the manufacturer.

Antimony combines with the other metals, and renders them brittle; and, as this effect was especially remarked in the case of gold, the alchemists distinguished it by the title of *regulus,* or the little king, from its power of ruling over the noble metal, and destroying its malleability. The chief alloys of antimony are *type-metal,* consisting of 4 lead and 1 of antimony; *stereotype-metal,* 6 lead and 1 antimony; *music-plates,* consisting of lead, tin, and antimony; *Britannia-metal,* consisting of 100 parts tin, 8 anti-

mony, 2 bismuth, and 2 copper. *Pewter* is sometimes formed of 12 parts tin and 1 part antimony. Antimony is also used in medicine, its two most important compounds being *antimonial powder* and *tartar-emetic:* the former, also called *James's powder*, is said to consist of 43 parts phosphate of lime and 57 oxide of antimony; the latter is a tartrate of potassa and antimony. Antimony is also used in the preparation of some enamels and other vitreous articles.

Great Britain receives the larger portion of its supply of antimony from Singapore, which receives it from Borneo. It is imported in the shape of ore, and commonly as ballast.

ANVIL. An instrument on which malleable metals are placed during the process of hammering. Anvils are sometimes made of cast-iron, but when required to be very hard or bright they are made of wrought iron and faced with steel. In such case the core or body is prepared at the forge, by welding together a number of rude blocks of iron. When the core is rudely shaped, three square holes are made in it, one in the bottom and one at each side, for the purpose of receiving a bar of iron connected with a crane near the forge, by which the anvil is held in the fire, and turned about while being forged. The common smith's anvil consists of seven pieces:—1, the core, or body; 2, 3, 4, 5, the four corners for enlarging the base; 6, the projecting end, containing a square hole for the reception of a set or chisel in cutting pieces of iron; and 7, the beak, or conical end, which is used for turning pieces of iron into a circular form, for welding hoops, &c. All these pieces are separately welded to the core. When the anvil is of large size two hearths are used, in one of which the core is raised to the welding heat and in the other the piece. They are then taken out and welded together by rapid hammering until they cohere. The whole is then heated again, and hammered until the proper shape is obtained.

The best anvils are faced with steel. This steel facing is shaped, heated, and laid on the anvil at a welding heat, the facing, however, being less heated than the anvil, and hammered rapidly until it is closely united: the whole is then finished by repeated heatings and hammerings. The anvil is next hardened by raising it, but especially the face, to a full red heat, and quenching it in a large quantity of cold water. It is of importance to cool it rapidly, and for this purpose a stream of water is to be preferred. In this process the steel facing will sometimes crack, unless it is thin. Should the hardening be successful, the facing is ground until it is perfectly even, and the edges are made sharp or round as required. When the anvil is to be used for planishing metals, it is polished with emery and crocus.

The smith's anvil is generally placed on a loose wooden block, such as the root end of an oak tree. Anvils used for cutting and for files are inserted into large blocks of stone. The more firmly the anvil is connected with the earth, the more effective is the blow of the hammer.

Locksmiths use a smaller kind of anvil called the *stake*, which is moveable, and is usually placed on the work-bench. It is used for setting small cold work straight, or for cutting or punching on with the cold chisel, or cold punch.

AQUA FORTIS. A common term, first applied by the alchemists to dilute NITRIC ACID, on account of its strong corrosive action on many animal, vegetable, and mineral substances.

AQUA REGIA. A term applied by the alchemists to a mixture of nitric and hydrochloric acids: it has the property of dissolving gold, which neither of the acids possesses separately. Two parts of hydrochloric and one of nitric acid are most effective. A partial decomposition of both acids takes place, and water, chlorine, and nitrous acid are the result. When a metal is placed in aqua regia it absorbs the chlorine, and is dissolved. This acid is the common solvent of gold and platinum.

AQUEDUCT, a conduit or channel for the conveyance of water, from the genitive case of *aqua*, water, and *ductus*, a conduit; hence the old method of spelling this word, *Aquæduct*, is more correct than the present. According to this derivation, any pipe or channel for the conveyance of water is an aqueduct; but the term is usually limited to those structures of masonry which are elevated above ground for the purpose of conveying a stream of water in a regular but slightly descending current across valleys and over plains.

An abundant supply of pure and wholesome water is essential to the health and prosperity of every town and city, and accordingly we find that in all ages and countries special provisions have been made to secure so desirable an object. The ruins of the aqueducts constructed in Palestine in the reign of Solomon still remain, and travellers describe the *Pools of Solomon* in connexion with a scheme for supplying Jerusalem with water. In the ruined cities of Central America, which still excite the astonishment of the traveller, the remains of aqueducts are also found; but of all the ancient aqueducts those of the Romans are most calculated to excite admiration, constructed as they were to pour into the city whole rivers of water for the use of the public baths, fish ponds, artificial lakes, gardens, villas, and private houses within and around the city. Some of these aqueducts extended thirty, forty, and even sixty miles from the city, in one continuous covered channel of stone, which was carried by means of arcades over the widest and deepest valleys, and by tunnels for miles through mountains and the solid rock. It is indeed a matter of painful regret that with our vastly increased engineering skill and improved means, the metropolis of a powerful nation like Great Britain should continue to languish and to suffer disease and misery, for want of an abundant supply of pure water.

Our knowledge of the aqueducts of ancient Rome is derived as well from repeated surveys of the stupendous ruins which still exist, as from a special treatise on the subject by Frontinus, who was

curator of aqueducts under the Emperor Nero. We learn from this excellent authority,[1] that for about 400 years after the building of the city, water was supplied by the Tiber, or by wells and fountains; but as the population became greatly increased, the Censor, Appius Claudius, constructed an aqueduct for bringing in the water of distant springs. Other aqueducts were afterwards constructed as the wants of the city required, and it became a fashion with the great men of the time to present the city with the munificent gift of an aqueduct. In the time of Frontinus the city was supplied by nine large aqueducts; five more were added by Nerva, and the number was increased by successive emperors to twenty. They were mostly named after the rivers or lakes which supplied them, or after the emperors who caused them to be constructed. The *Virgin Aqueduct*, however, was so called from the circumstance of a young girl showing some veins of water to a few soldiers who were in search of a spring. On following these veins by digging, an abundant supply was procured, and, "there is a painting," says Frontinus, "in a little temple erected close by the source, representing the event."

The most remarkable aqueducts of ancient Rome were the *Aqua Appia*, the *Old* and the *New Anio*, the *Aqua Martia*, which also conveyed the waters of the *Aqua Julia* and the *Aqua Tepula;* the *Aqua Virginia* and the *Aqua Claudia.* The Aqua Appia was named in honour of the Censor, Appius Claudius, by whom it was constructed in the 442d year of Rome. Its source was in a field near the Via Prænestina, between the sixth and the eighth mile-stones: it made a circuit of 780 paces to the left, and then proceeded by a deep subterranean channel of more than eleven miles, and entered the city at the Appian way by the Porta Capena, and delivered the main body of its waters into the Campus Martius. The Old and New Anio conveyed to Rome the waters of that river. The former began above the Tiber at the 30th mile-stone, and consisted mostly of a winding channel of 43 miles. The latter took a higher level, running a length of 7,543 paces above ground, and then through a subterranean passage, a length of 54,267 paces. The Aqua Martia rose from a spring 33 miles from Rome; it made a circuit of 3 miles, and afterwards forming a vault of 16 feet diameter, ran 38 miles along a series of arcades at an elevation of 70 feet. Openings were perforated at certain places, for the discharge of the collected air, and at different parts of its course were deep cisterns, in which the water deposited its solid contents. The water of this aqueduct was celebrated for its clear green colour, and was praised by Pliny for its coolness and salubrity. The triple aqueduct of the Aqua Martia consisted of three stories or conduits, placed one above the other. The uppermost conduit was the Aqua Julia, the middle one the Aqua Tepula, and the lowest the Aqua Martia. This accounts for the extraordinary height of this aqueduct, and from the ruins of it which still remain it is called *Il castel del Acqua Marcia.* The Aqua Virginia was constructed by Agrippa: its source was a very copious spring, in the midst of a marsh 8 miles from the city, but its channel was about 12 miles, a portion of which was through a tunnel 800 paces in length. The Aqua Claudia was commenced by Nero and completed by Claudius; it rose 38 miles from Rome, and formed a subterranean stream of 36½ miles, then ran 10¾ miles along the surface of the ground: it was vaulted for a space of 3 miles, and was supported on arcades through 7 miles, being carried along a level sufficiently high to supply all the hills of Rome. It was constructed of hewn stone, and of such excellent workmanship, that after withstanding the attacks of time during many centuries, and the still more destructive attacks of barbarians, it was found sufficiently perfect to be restored by Sixtus V., and it furnishes the modern city with water of the best quality. This aqueduct was named *Aqua Felice*, in honour of Sixtus V. whose conventual name was *Fra Felice*, or "Brother Felix."

It will be seen that in some of these aqueducts the length of the channel was greater than that of the roadway between the city and the source of the aqueduct. This was necessary to ensure a very gentle fall for the channel; for, if the source of the water conveyed were much higher than where it was to be delivered, the pressure of water from the head would burst or blow up the covering arch or coping of the aqueduct, and thereby render the structure useless, and inundate the district over which it was attempted to convey it. Hence in order to reduce the flow of water to the proper velocity, the stream had frequently to be carried in a winding direction so as to expend

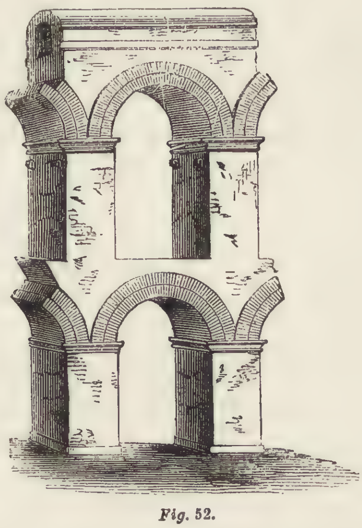


Fig. 52.

the height in a greater length. In all these aqueducts the whole channel was regularly built of stone or

(1) An excellent edition of this author is that published by Rondelet, with the Latin text on one side and a French translation on the opposite page. It is entitled, "Commentaire de S. J. Frontin sur les Aquéducs de Rome. Par J. Rondelet," Paris 1820. The work is accompanied by an Atlas of 31 large copper plates. The reader who desires further information, should also consult Fabrettus, "De Aquis et Aquæductibus veteris Romæ," 4° Rom. 1680.

brick, and arched above to cover in the channel, so as to protect the water from impurities and evaporation. In crossing valleys the conduit was raised upon a series of arches with massive piers and of solid substantial structure, sometimes of brick, and often of hewn stone. When the height was not very great a single row of arches sufficed, but in other cases a double row was constructed as in Fig. 52. Many of these works exceed in magnitude even those portions of our modern railroads which have been the admiration of our age. The aqueduct of New Anio, for example, consisted during $6\frac{1}{2}$ miles of one continuous series of arches, many of which were upwards of 100 feet high. In the 38 miles which formed the length of the Aqua Martia, there were nearly 7,000 arches. The New Anio conduit was 63 miles 700 paces in length, of which 49 miles 200 paces formed a subterranean stream; in 9 miles 400 paces the conduit was above ground, and some of the arches 109 feet.

The following table represents the supply of water to Rome from the nine earlier aqueducts. It has been constructed from the data furnished by Frontinus :—

Name of the Aqueduct.	Era of its construction.	Length in miles.	Cubic feet of water discharged in 24 hours.	Gallons in Wine Measure.
1. Appian Aqueduct ...	B.C. 312	10.3250	3,706,575	27,724,181
2. Old Anio	,, 273	36.6775	8,932,338	66,813,887
3. Marcian	,, 146	56.9417	9,525,390	71,249,917
4. Tepulan	,, 127	14.2341	903,795	6,760,386
5. Julian	,, 35		2,449,386	18,321,407
6. Virgin	,, 22	14.3116	5,085,624	38,040,467
7. Alsietina	A.D. 14	20.4526	796,152	5,625,016
8. Claudian	,, 49	42.1989	9,356,817	96,988,991
9. New Anio	,, 90	54.1644	9,622,878	71,979,127
		249.3058	50,378,955	376,834,379

Some auxiliary supplies or feeders make the total length of the Roman aqueducts at that period to exceed 255 miles.

Modern Rome is also abundantly supplied with water, either by means of new aqueducts, or by the ancient structures which have been repaired.

In the cities of the provinces of the vast Roman Empire were conduits and aqueducts on as large a scale as those which supplied the capital of the empire, and in some cases larger. Our limited space will not allow us to notice more than one of these, viz. the Aqueduct of Nismes, which is, perhaps, the most remarkable Roman remain of the kind, surpassing even the aqueducts of Rome in lightness and striking boldness of design. That portion of the aqueduct which crosses the river Gardon, and hence called the *Pont du Gard*, (Fig. 53,) is thus noticed in Murray's *Hand-Book for Travellers in France:* "The sight of this noble edifice, one of the grandest monuments which the Romans have left behind them in France or any other country, would well repay for a very long detour. Like Stonehenge, it is the monument of a people's greatness, a standard by which to measure their power and intellect. It consists of 3 rows of arches, raised one above the other, each smaller than the one below it; the lowest of 6 arches, the central tier of 11, and the uppermost of 35; the whole in a simple, if not stern style of architecture, destitute of ornament. It is by its magnitude and the skilful fitting of its enormous blocks that it makes an impression upon the mind. It is the more striking from the utter solitude in which it stands, a rocky valley, partly covered with brushwood and greensward, with scarcely a human habitation in sight, only a few goats browsing. After the lapse of sixteen centuries, this colossal monument still spans the valley, joining hill to hill, in a nearly perfect state, only the upper part at the north extremity being broken away. The highest range of arches carries a small canal about 5 feet high and 2 feet wide, shaped like the letter U, just large enough for a man to creep through, still retaining a thick lining of Roman cement. It is covered with stone slabs, along which it is possible to walk from one end to the other, and to overlook the valley of the Gardon. The arches of the middle tier are formed of 3 distinct ribs or bands, apparently unconnected. The height of the Pont du Gard is 180 feet, and the length of the highest arcade 873 feet. Its use was to convey to the town of Nismes the water of two springs 25 miles distant, the Airan rising near St. Quentin, and the Ure near Uzès. It forms only a small portion of the conduit constructed for this purpose, whose course, partly raised on low arches, some of which exist on the north of the Pont du Gard, partly cut in the rock round the shoulders of the hills, may be traced at the village of St. Maximin near Uzès, and above that of Vers, to the Pont du Gard; thence, by St. Bonnet and Sernhac, to the hill of the Tour Magne and Bassin des Thermes at Nismes. The conveyance of this small stream was the sole object and use of this gigantic structure, an end which would now be attained by a few iron water-pipes. Its date and builder are alike lost in oblivion, but it is attributed to M. Agrippa, son-in-law of Augustus, B.C. 19. The quarry whence the stone was obtained is a little way down the Gardon, on its left bank. The bridge by which the road crosses the Gardon on a level with the lower tier of arches, and formed by merely widening them, is a modern addition to the ancient structure, having been erected in 1743 by the States of Languedoc."

The Pont du Gard above described occupied about a medium position in the acqueduct, which was nearly 30 miles in length, forming in its course the figure of a horse-shoe. The channel way was of stone throughout. The bottom of the interior had a curved form, being an arc of a circle; the sides were vertical, and the top was covered with a flagging of cut stone, except where the chanel ran underground, in which case it was covered by an arch of stone. The interior face of the walls and bottom of the conduit was covered with a coatig of plaster 2 inches thick, composed of quick lime, fine sand and brick nearly pulverized. This coatig has now a tenacity equal to the hardest stone. The size of the channel way is 4 feet wide, and $5\frac{1}{3}$ feet high, except where it was covered by an arch, in which case it was $7\frac{1}{2}$ feet high in interior dimensions The descent was 1 foot in 2,500, or $2\frac{11}{130}$ feet per mile. The water formed a deposit of lime on the sides of the

channel, until nearly half the channel was closed, this deposit being 11 inches thick on each side. This aqueduct appears to have been in use for more than 4 centuries, and now, after the lapse of 14 centuries, it is in such good preservation that it could be restored without any very considerable outlay.

In modern times the French have imitated the Romans in the construction of aqueducts. The aqueduct for conveying water from Versailles to Marli was built by Louis XIV. at great expense. The famous aqueduct bridge of Maintenon was erected for conveying the waters of the river Eure to Versailles. This magnificent structure is 4,400 feet in length, or nearly $\frac{7}{8}$ of a mile, and is upwards of 200 feet high; it consists of 242 arcades, each divided into 3 rows, making in all 726 arches of about 50 feet span.

It is frequently stated, that had the Romans been aware of the principle that water seeks the level of its source after encountering depressions in its conduit, they might have spared themselves the immense labour and cost of constructing their colossal aqueducts, by forming an inverted syphon of pipes across valleys. It might as reasonably be argued that the modern French and Americans were ignorant of this principle, because they have preferred the stone conduit to the system of pipes. The fact is, that the Romans were fully aware of the principle in question, as is proved by the remains of many of their works, but they preferred a system of stone channels, not only on account of the greater permanence and durability of the work, but also on account of the greater abundance of the supply of water which this method secured, and its greater purity. In considering the best method of supplying the city of New York with water from the Croton river, situated at a distance of 38 miles from that city, it was calculated that a system of iron pipes would be more costly than an enclosed stone channel, and far less durable. An open canal was also objectionable on account of the loss of water by filtration through the banks, and by evaporation. Another objection to the open canal was the difficulty of preserving the water from receiving the wash of the country through which it passed, and of preventing injurious matters from being thrown into it and rendering it impure; impurities might also be contracted in passing through different earths; frost would also interfere with the supply. When we find an enterprising and intelligent nation like the Americans adopting the system of the ancient Romans, it is difficult to suppose that the same reasons did not in both cases lead to the adoption of the same method. When the system of sewage and water supply of modern London shall exceed that of ancient Rome, we shall then, and not till then, be in a condition to accuse the old masters of the world of ignorance.

In the magnitude of our metal castings for pipes, the moderns are certainly superior to the ancients, and in some cases a system of iron pipes has been used to supply a city with water. Such is the case at Edinburgh, which is supplied by the Crawley Spring from the rising ground on the south base of one of the Pentland Hills. The distance is scarcely 7 miles from Edinburgh in a straight line, but it is $8\frac{3}{4}$ miles by the line of pipes. The spring is 564 feet above the level of the sea, and 360 feet above the level of the reservoir in Princes Street. The original issue of the spring is augmented by a drain carried about half a mile above the spring, up the valley in which the spring is situated. The soil of the valley is of gravel 40 feet deep, forming a vast natural filter, through which the water from the high grounds on each side percolates. The water is thus rendered very pure, and being all intercepted by the drain, is conducted with the original discharge of the spring into a reservoir or water-house, from which the pipes take their rise, and continue in one connected train to the city. For the first 3 miles the pipes are from 18 to 20 inches in diameter, and afterwards 15 inches. As they approach the city they are carried through a tunnel under Heriot's Green, and another under the Castle Hill through the solid rock. By means of a reservoir, branch-pipes and service-pipes, the water is supplied to each house or floor of a house. Air-cocks are placed at intervals all along the main pipes, to let off the accumulated air, which is done by hand every three or four days. The average supply of water by this aqueduct is 180 or 200 cubic feet per minute, and it is stated that double this quantity could be easily supplied. The water is said to be of the finest quality; it issues from a deep source and at a great altitude, so that it is fresh and cool even in the heat of summer. In this respect the supply of Edinburgh is far superior to that of most other towns of the same magnitude. The elevated nature of the country about the city affords facilities for distributing the water without the aid of machinery.

Aqueduct bridges were first used in this country for the canals constructed by the Duke of Bridgewater, under the direction of Brindley. The first and largest was the aqueduct at Barton Bridge, for conveying the canal across the Irwell, 39 feet above the surface of the river. It consists of three arches, the middle one 63 feet span, admitting under it the largest barges which navigate the Irwell, with sails set. This aqueduct bridge was commenced in September 1760, and in the July of the following year, the singular spectacle was first seen in this country of vessels sailing across the course of the river, while others in the river itself were passing under them. So little were engineers acquainted with works of this kind at the time of its erection, that when, at the request of Brindley, an eminent engineer was called in to give his opinion respecting the proposed aqueduct, he said with a sneer, "I have often heard of castles in the air, but never before was shown where any one of them was to be erected."

Allusion has been already made to the construction of aqueducts on a large scale in the United States of America, by improving on the model of the ancient Romans. New York had always been badly

supplied with fresh water: the quantity collected, chiefly from wells, was small and the quality bad. So long back as the year 1798, Dr. Brown, in an official report, considered these as the chief causes of the yellow fever and other contagious diseases which so frequently ravaged the city. He shows that the well-water, although cool and pleasant to the taste by the admixture of carbonic acid, was nevertheless contaminated with the filth of men and animals, which sinks into the streets, yards and stables, and then drains through the cemeteries, before it reached the collecting pond. The water was so bad that the ships in the harbour could not use it at all, but brought their supply from other seaports. At length the citizens became fully impressed with the necessity of obtaining a plentiful supply of pure water, by the ravages of the yellow fever in the summer of 1822, and of the cholera in 1832. After some preliminary proceedings, an Act was passed in May 1834, appointing five Water Commissioners, with powers to examine and consider all matters relative to the supply of the city of New York with a sufficient quantity of pure and wholesome water, and to adopt such plans as in their opinion would be most advisable for securing such supply. After much careful inquiry it was decided that the Croton river was the only source that could be depended on for present and future purposes, to ensure a sufficient quantity at all seasons at an elevation precluding the use of steam or other extraneous power, and that the quality of the water was unexceptionable. The distance of the Croton

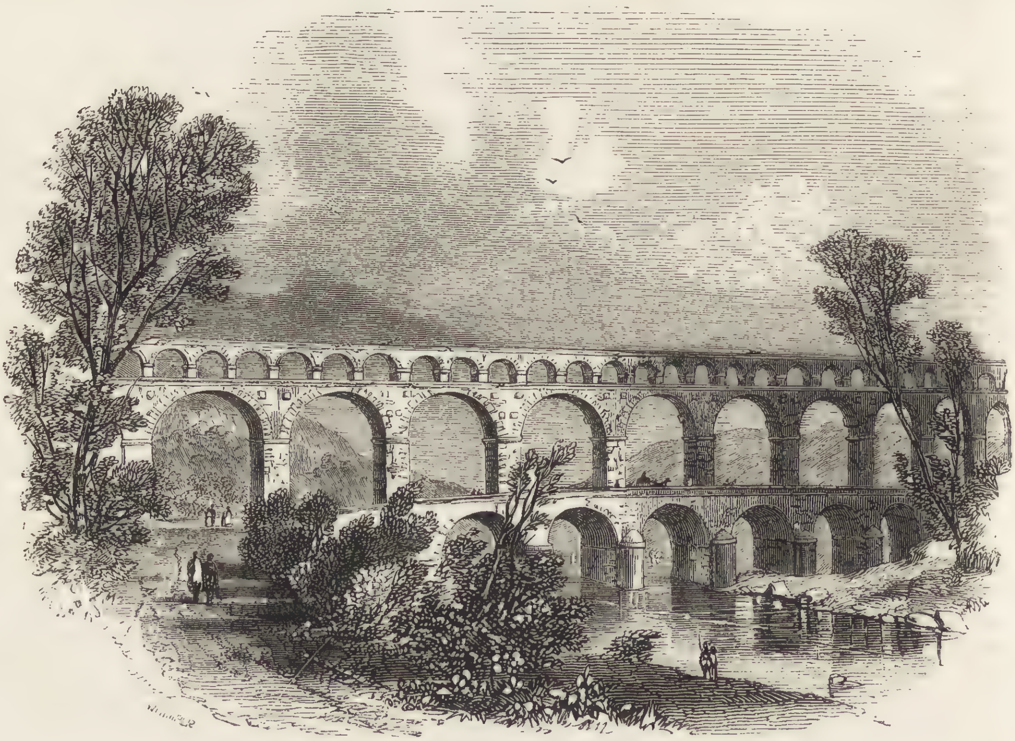


Fig. 53. AQUEDUCT OF NISMES AT THE PONT DU GARD. (*See page* 62.)

river from New York is about 40 miles, over a country extremely broken and uneven, and following a direction for a part of this distance parallel with the Hudson river, and encountering the streams which empty into it and form deep valleys in their courses. To convey this water to the city, it was decided to erect a close channel or conduit of masonry.

The sources of the Croton are principally in the county of Putnam, fifty miles from New York; they consist mostly of springs, which in that elevated and uneven country have formed many ponds and lakes never failing in their supply. About 20 of these lakes form the sources of the Croton river, and the magnitude of their surface areas is about 3,800 acres. The country is sufficiently cleared to prevent any injury to the water from the decay of vegetable matter. The river has a rapid descent, and flows over a bed of gravel and masses of broken rock, and the water is so pure that in earlier days the native Indian called it "the Clear Water."

Having ascertained the elevation in the city at which it would be desirable to distribute the water, it was only necessary then to find a point on the Croton river where a dam could be constructed, so as to turn the water into a channel gradually descending from this point through the whole length of the aqueduct to the required elevation in the city. At the spot where it was decided to construct the dam across the Croton river, the surface of the natural flow of water was about 38 feet below the elevation required as a head from which the water was to flow into the channel of the aqueduct. By

going farther up, a dam of less height would have sufficed, but in that case some important tributaries of the Croton would have been lost. The medium flow of water in the Croton, where the Fountain Reservoir was formed, exceeds 50,000,000 gallons in 24 hours, and the minimum flow after long droughts is about 27,000,000 within the same period. The dam sets the fountain back about 6 miles, thus forming the Fountain Reservoir, which covers an area of about 400 acres, forming a beautiful sheet of water in the lap of the hills, in the wild region of the Croton. It has received the name of the "Croton Lake." The country forming the valley of the river was such as to give in general bold shores to this reservoir, and in cases where there was a gentle slope or level of ground near the surface of the water, excavations were made so that the water should not be of less depth than $4\frac{1}{2}$ feet. In this reservoir the water collects and settles before it flows into the aqueduct. The available capacity of this reservoir down to the level at which the water would cease to flow off into the aqueduct, is estimated at 600,000,000 gallons; so that if the number of inhabitants of New York be estimated at one third of a million, the Fountain Reservoir would contain a supply for 90 days in a season of extreme drought; in addition to which, the Reservoir in the city would afford a further supply of about 25 days, thus providing for a season of 4 months' drought. Should the population greatly increase, other streams can be turned into the upper branches of the Croton, or into the aqueduct along its course. Other reservoirs might also be constructed further up the Croton, to draw from in time of need.

From the Fountain Reservoir on the Croton to the Receiving Reservoir on the Island of New York, a distance of 38 miles, no essential change was made in the form of the channel way, except in crossing Harlem river to reach the island, and also in passing a deep valley on the island, in both which cases iron pipes were used instead of the channel way of masonry. At these points the iron pipes descended and rose again, so that when water is flowing in the channel they are completely full. The channel way of masonry is never filled entirely, so as to occasion a pressure on its interior surface. To prevent this, 6 waste weirs were constructed at suitable places, to discharge the surplus water: they were formed on one side of the channel way, so as to allow the water to flow off when it rose above a certain level.

The following figures will show the kind of work employed in constructing the channel. Fig. 54 is a section of the aqueduct, showing the form of masonry used in earth excavations. The foundation was formed with concrete, the side walls are of stone, and the bottom and sides of the interior faced with brick, and the top covered with an arch of brick. After the masonry was finished, the excavation was filled up around it, and over the top of the roofing arch, generally to the height of 3 or 4 feet, and in some cases of deep excavation up to the natural surface.

Fig. 54.

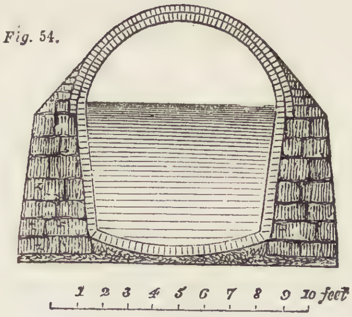
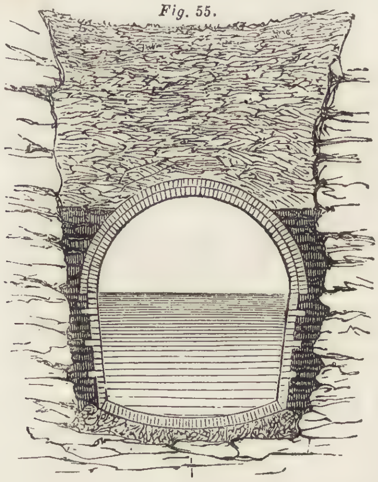


Fig. 55 is a section of the aqueduct in open cuttings in rock. The rock was excavated to the required

Fig. 55.



depth and width; the bottom was levelled up with concrete to the proper height and form for receiving an inverted arch of brick; the side walls were of stone and brick bonded together, and built closely against the sides of the rock and forming a junction with it. On the exterior of the roofing arch, a heavy spandril of stone masonry was built, filling the space between the arch and the rock. After the masonry was finished, the excavation above it was filled with earth.

Fig. 56.

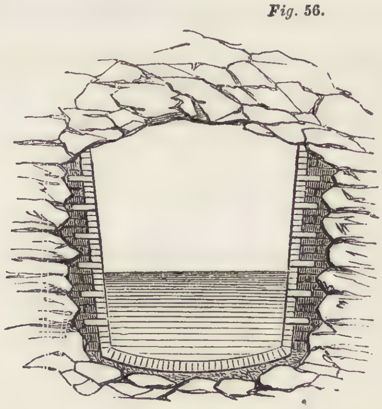
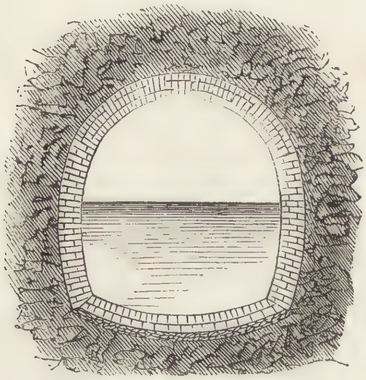


Fig. 56 is a section of the aqueduct in rock tunnel cuttings. The natural rock often served as a roof

for the channel way where the rock was sound, but where soft a brick arch was built over the channel way, and the space between its extrados or outer surface was filled with earth closely rammed around it. In some instances, where the perforated rock was at first quite hard, the natural roofing became, by exposure to the air, soft and insecure, so as to render it necessary to turn an arch for its support; a difficult operation after the tunnel had once been formed.

Fig. 57 is a section of the aqueduct in earth tunnel

Fig. 57.



cuttings. When the earth was dry and compact, the excavation for the bottom and sides was made of the proper form to receive the masonry built closely against it. The top of the excavation was made sufficiently high to give room to turn the arch, and the space above was filled with earth closely rammed in. Where the earth was wet, the excavation was made larger, and props of timber and plank were used to support the top and sides until the masonry was completed; the whole exterior space was then compactly filled with earth.

In carrying the aqueduct across valleys, it was supported on a foundation wall of stone laid dry, and sloping embankments of earth were then constructed on each side.

Over the aqueduct were erected ventilating shafts of stone, rising about 14 feet above the ground. One of these was erected every mile, and every third shaft was furnished with a door to afford entrance to the aqueduct for the purposes of inspection and repairs. Openings 2 feet square were also made in the top of the roofing arch every quarter of a mile. Each opening was covered with a flag-stone, and the spot marked by a small stone monument projecting above the surface. The object of these openings is to obtain entrance or to increase the ventilation if necessary.

In places where streams intersect the line of aqueduct, culverts or stone channel ways were erected, to allow the water to pass under, and to pursue its natural course without injury to the work.

At the head of the aqueduct is a tunnel and a gate-chamber in connexion with the Fountain Reservoir, as shown in the longitudinal section, Fig. 58. This gate-chamber is not connected with the dam itself, but stands at some distance from it, and the water reaches it by means of the tunnel, T, which leaves the reservoir, S R, above the dam, and passes through the solid rock of the hill against which the masonry is built, a distance of upwards of 200 feet. This tunnel descends into the Reservoir, so that the centre of it at the mouth is about 12 feet below the surface of the water. This prevents floating substances from entering it, and during winter, when the water is frozen over, there is no obstruction to the flow into the aqueduct, A, and during summer the water is drawn from a level where it is cooler than at the surface.

The gate-chamber has two ranges or sets of gates; one set called *regulating gates*, R G, and the other *guard gates*, G G. The regulating gates are made of gun-metal, and work in frames of the same material, which are fitted to stone jambs and lintels; the guard

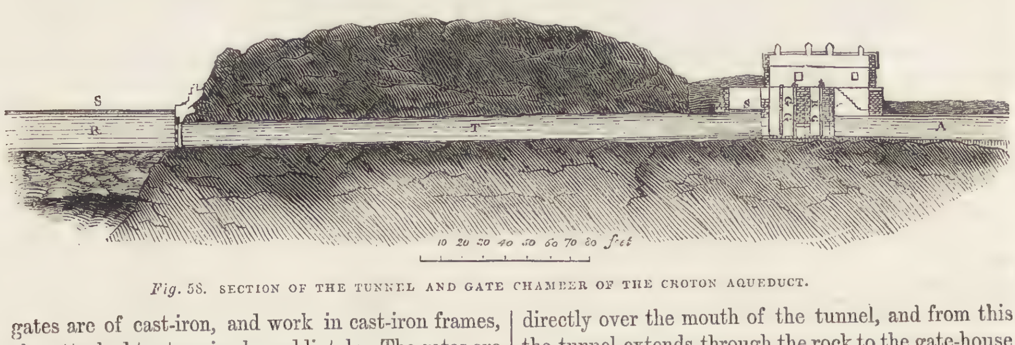


Fig. 58. SECTION OF THE TUNNEL AND GATE CHAMBER OF THE CROTON AQUEDUCT.

gates are of cast-iron, and work in cast-iron frames, also attached to stone jambs and lintels. The gates are managed by means of wrought-iron rods attached to them, having a screw formed on the upper part on which a brass nut works, being set in a cast-iron socket cap.

The accompanying view, Fig. 59, is taken above the dam, showing the position of the entrance to the tunnel leading from the reservoir to the gate-chamber. The entablature on the left against the rock is built directly over the mouth of the tunnel, and from this the tunnel extends through the rock to the gate-house seen on the right of the view, and at some distance from the dam. In the centre, on the ridge of the dam, is a gate-house over a culvert which extends through the body of the dam. This culvert is 30 feet below the surface of the water when the reservoir is full, and has gates opening by rods rising into the house. When the river is low, the water which is not drawn off by the aqueduct can pass

through this culvert, and allow none to pass over the dam.

The bottom of the water-way of the aqueduct,

Fig. 59. THE CROTON LAKE AND DAM.

where it leaves the gate-chamber, is 11.40 feet below the surface of the Fountain Reservoir, and 154.77 feet above the level of mean tide at the city of New York. The length of the aqueduct as it is divided into different planes of descent, from the gate-chamber at the Croton Dam to the gate-chamber at the Receiving House on the Island of New York, is as follows:—

	Feet.		*Miles.*		*Feet.*
The first plane of aqueduct extends	26,099.72	or	4.943,	and the descent	2.94
The second ditto	148,121.25	,,	28.053	,,	30.69
Length of pipes across the Harlem River	1,377.33	,,	0.261		
Difference of level between the extremes of pipes	......		......	,,	2 29
The third plane of aqueduct extends...........	10,733.14	,,	2.033	,,	2.25
Length of pipes across the Manhattan Valley	4,105.09	,,	0.777		
Difference of level between the extremes of pipes	......		......	,	3.86
The fourth plane of aqueduct extends......	10,680.89	,,	2.023	,,	1.60
	201,117.42		38.090		43.63

The descent on the first plane is about $7\frac{1}{8}$ inches per mile; on the second and third planes about $13\frac{1}{4}$ inches per mile; and on the fourth plane about $9\frac{1}{2}$ inches per mile.

The bottom of the water-way of the aqueduct at the gate-chamber, where it enters the receiving reservoir, is 7.86 feet below the level of the top water-line in the reservoir; so that when the reservoir is full, the water will rise to within $7\frac{1}{4}$ inches of the top of the interior of the aqueduct at that place, and the height from the top water to the top of the interior will increase according to the plane of the aqueduct grade, until it reach the surface level of the flow of water in the aqueduct.

The height of the interior of the aqueduct is 8 feet $5\frac{1}{2}$ inches, and the greatest width is 7 feet 5 inches. The sectional area of the interior is 53.34 square feet. On the first plane the aqueduct is larger, being 2.05 feet higher at the gate-chamber, 2.31 feet higher at 2,244 feet from the chamber, and diminishing to the head of the second plane, where it is of the dimensions above mentioned, and continues the same throughout, except in tunnels, where the dimensions are those already stated.

The curves used to change the direction of the line of the aqueduct are generally formed with a radius of 500 feet; some have a radius of 1,000 feet; and in a few instances even larger ones have been adopted.

The velocity of the water in the aqueduct is about a mile and a half per hour, when it is 2 feet deep. This was determined by floating billets of wood from the Croton Dam to Harlem River, and noting the time of their passage. This would give the surface velocity, which is greater than that of the whole body of water in the aqueduct; but, as the working depth is 4 feet, there is a corresponding increase in the velocity of the body of water: hence, the velocity of a mile and a half an hour may be taken in general terms as the velocity of the water in the aqueduct.

The Receiving Reservoir, into which the aqueduct discharges its water, occupies an elevated part of the island of New York. It is 1,826 feet long, and 836 feet wide, from outside to outside, at the top of the external walls of the embankment, making altogether an area of 35 acres. In this, as in almost every instance of excavation, the rock was found above the proposed bottom of the excavation; and the difficulties of preventing leakage along the surface of the rock were great. The natural veins and fissures of this gneiss formation, and the partial unsoundness of the rock, rendered leakages still more probable; but all this was overcome by the skill of the engineers. The embankments of the reservoir were made of good assorted earth, and a portion of the bank was puddled, or made compact and impervious by wetting the earth and using a spade to force it into a compact state. The embankments were about 20 feet wide on the top, and increased in thickness towards the base by sloping on both sides. The outside face was protected by a stone wall, 4 feet thick, with the face laid in mortar; the inside face was protected by a sloping wall of stone, $1\frac{1}{4}$ feet thick, laid without mortar. The top of the bank is 4 feet above the top water-line, and the inside sloping wall terminates 2 feet above the top water-line, leaving the remainder of the face to be covered with grass, so as to present a belt of green above the water on the bank all round the reservoir. A neat fence bounds the outside and the inside of the top bank, forming a walk of a mile in length round the entire reservoir. The reservoir is formed into distinct divisions: the greatest depth of the water in the north division is 20 feet, and in the south division 30 feet; but the whole of the rock to these depths was not excavated. The capacity of the reservoir, when both divisions are full, is 150,000,000 imperial gallons. The aqueduct enters a gate-chamber in the south division, where there are regulating gates for discharging the water into either division by a continuation of the aqueduct within the reservoir. There is also a connexion-pipe of cast-iron, for allowing the

water to flow from one division into the other, so as to equalize the level. There is also a waste-weir for draining off the surplus water into a sewer. Mr. Towers remarks truly, that this beautiful lake of pure water resting on the summit of the island is truly a pleasing object, and, considering its size, is what no other city can boast of having within its limits.

From the Receiving Reservoir the water flows, by means of large pipes, a distance of two miles, into the Distributing Reservoir, situated within the city, the object being to have a sufficient head of water near the densely-populated parts. Fig. 60 is an isometrical view of this reservoir. The pipes from the Receiving Reservoir enter it at the base of the central pilaster. The flow of water is regulated by stop-cocks; and a door in the pilaster affords an entrance to the vault in which the stop-cocks are situated. This reservoir is divided into two parts by means of a wall. On the south side of the reservoir a pipe, 3 feet in diameter, proceeds from each division to the supply pipes, so arranged as to draw from one or both divisions. The house standing across the dividing wall is situated directly over the mouth of the effluent pipes, which leave the reservoir at the base of this pilaster. The water is distributed over the town, through 134 miles of pipe, of all sizes, between 36 and 4 inches bore. By this means also several public and private fountains are supplied. Feed-pipes, from half-an-inch to 1 inch bore, are led from the main-pipes into the basement of every house, and in many cases a pipe rises to the bed-rooms, for supplying baths, &c. The mains are also furnished with muzzles, to which the engine-hose of fire-engines can be screwed, for extinguishing fires; and at the harbour pipes are branched out, terminating at the bulwarks, for supplying ships, and filling the water-casks on board, by means of a hose. The Distributing Reservoir is 425 feet square, measuring from the top

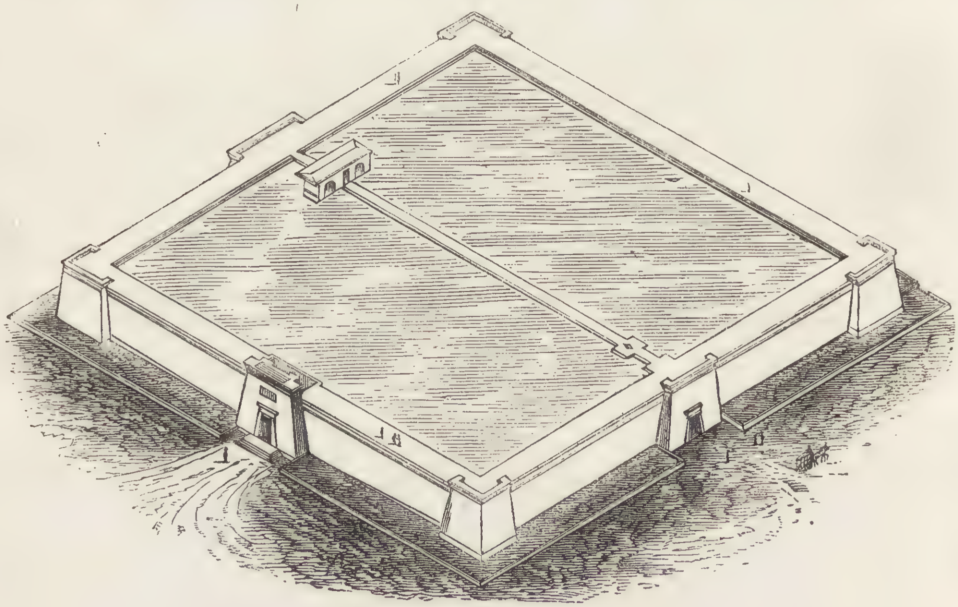


Fig. 60. THE DISTRIBUTING RESERVOIR.

of the corners of the main wall, and 436 feet square at the base. It covers a little more than 4 acres. Its height is 45 feet above the neighbouring streets, and about 50 feet above the foundations. Its capacity is 20,000,000 gallons. The outside walls are constructed with openings in them, so that by entering a door one may walk entirely round the reservoir, within the walls. The object of this construction was to obtain a greater breadth with a given quantity of material, and also to afford an opportunity of examining the work, so as to guard against leakages, and to prevent any moisture from finding its way through the exterior, so as to cause injury to the wall by freezing. This kind of open-work rises to within about 8 feet of the top of the water-line. Inside these walls is an embankment of puddled work, formed with a suitable breadth of base to give security to the work, and the face of this embankment next the water is covered with a wall of hydraulic masonry $1\frac{1}{4}$ foot thick. The top of the embankment is covered with a stone flagging, forming a walk round the reservoir, and is bounded by an iron railing. The exterior of the reservoir is built on a slope of one-sixth its height, and an Egyptian cornice projects at the top of the main wall and pilasters. Terraces are formed at the foot of the walls, covered with grass, giving a rich finish to the work.

This reservoir may be considered as the termination of the Croton Aqueduct. Its distance from the Fountain Reservoir on the Croton River is $40\frac{1}{2}$ miles. The cost of this noble work amounted to 8,575,000 dollars, including the purchase of land and extinguishing water rights and some unfinished works. This amount is within 5 per cent. of the estimate of the chief engineer, Mr. John B. Jervis. To this sum must be added 1,800,000 dollars, as the cost of

the distributing pipes. The first two millions were raised at interest of 7 per cent., and is payable from 1847 to 1857 : 5 per cent. interest was charged for the remainder, to be redeemed from 1858 to 1880. A discount of 647,157 dollars was charged for issuing the loan, which, together with the interest paid during the construction of the work, brings the total expense to 12,500,000 dollars. The annual interest for this capital amounts to 665,000 dollars, which is raised by a direct water-tax and some indirect taxes. By means of an existing sinking-fund the capital will be gradually redeemed. The water-tax amounts to 10 dollars for a house of middle size, and there are more than 33,500 houses in the city. Manufactories, hotels, bathing houses, distilleries, livery-stables, breweries, slaughter-houses, &c., and ships, pay according to the rate of consumption.

The complete success of the Croton Aqueduct has stimulated other cities of the United States to adopt similar plans for obtaining a supply of pure water. The Boston Aqueduct is a worthy successor of the Croton.

Our chief authority for the details respecting the Croton Aqueduct is an excellent work, entitled, "Illustrations of the Croton Aqueduct," by F. B. Towers, of the Engineer Department; New York and London, 1843. We have also consulted Schramke's "Description of the New York Croton Aqueduct."

ARCH. [See BRIDGE.]

ARCHIL. ORCHIL. CUDBEAR. A violet dye obtained from several species of lichen, the most important of which are *Roccella tinctoria* and *fusiformis*, the dye of which makes litmus, and is largely used by manufacturers under the name of Archil or Orseille des Canaries, and *Lecanora perella* or *Orseille de terre*, and *L. tartarea* or Cudbear. Other species may be similarly employed, and the mode of testing is as follows :—The lichen whose properties are to be ascertained is placed in a glass bottle, and moistened with equal parts of ammonia and lime-water. A little hydrochlorate of ammonia is also added, and the bottle corked. In three or four days the small portion of liquid which will run off on inclining the bottle, will perhaps be tinged with crimson, and the plant itself will assume the same colour. If so, the lichen will yield a dye similar to that of Roccella tinctoria. The last named lichen or Archil plant is abundant in the Canaries and Cape Verd islands, and in the Levant. Pliny describes it as growing on the rocks of Candia and Crete, and says that the first tint or ground colour of the costly purple was given with the dye obtained from this plant. So in the present day, archil is chiefly used to improve other colours, and give richness and brilliancy to them, being too fleeting to be employed alone. The use of this dye was revived in Italy in the fourteenth century by a Florentine, who enriched himself and his country by making it a branch of commerce. The Spanish name of the lichen was Orciglia, and this became Oricella or Orchella, and the family who had revived the manufacture Oricellarii, afterwards corrupted into Rucellari and Rucellai, a name still found among the first families in Florence.

This lichen has an upright growth of about two inches, and when old is crowned by flat, round disks. The colour varies from white to dark grey. The several lichens employed in this dye are largely exported from the places where they grow, and are in considerable request at the ports of London, Amsterdam, and Marseilles. One hundred and thirty tons of the Lecanora tartarea are annually exported from Sweden. These lichens are principally collected on the rocks near the sea, and are frequently packed without any previous preparation. But it is necessary before using them, to clear and grind them into a pulp with water. Ammoniacal liquors derived from gas-works, or occasionally from urine, are gradually added, and the mass is frequently stirred so as to expose it to the action of the air. The colouring matter is thus evolved, and is afterwards pressed out and made into a paste with chalk and plaster of Paris. This is the archil of commerce.

Archil readily yields its colouring matter to both water and alcohol. A total exclusion of air from this substance destroys its colour as effectually as too much exposure. Thus in spirit thermometers in which the liquid is usually tinged with archil, if the exclusion of air is complete, the colour gradually fades away, but upon breaking the tube, the colourless spirit soon resumes its colour, and this fading and reviving may be carried on a number of times in succession.

One of the principal sources of colouring matter in lichens is a chemical substance called *orcine*, which reddens on exposure to the air. Orcine has a sweet but somewhat repulsive taste; its properties are perfectly neutral; it crystallizes in flat four-sided prisms.

In the dyeing of silks archil is frequently employed for lilac colours, hence their usually fleeting character; but with other hues this dye is merely used to modify or brighten, the silks being passed through a bath of archil to receive the peculiar bloom of that substance. The beauty imparted by this dye is a temptation to manufacturers to employ it too largely. Archil is employed with indigo in the woollen cloth manufacture, and produces a saving of indigo, while it gives a rich appearance to the blue or black cloth dyed with it, but this requires caution, and the bloom imparted is often deceptive. Archil cannot be made more durable by the ordinary means; a solution of tin appears to be the only substance capable of fixing it, and this changes the colour from violet to crimson.

A beautiful violet colour is imparted to marble by archil, and this is less fugitive than other forms of this dye.

The preparation called *Cudbear*, (Cuthbert,) is so named from Dr. Cuthbert Gordon, who took out a patent for this mode of preparation, and connected it with his own name.

ARCHIMEDEAN SCREW. [See SCREW.]

AREOMETER. [See HYDROMETER.]

ARGAND LAMP. This valuable invention has been named in honour of the inventor Ami Argand,

a native of France, who in 1789 contrived a burner consisting of two metallic cylinders one within the other, the annular space between them, which is closed at the bottom, containing oil and a cylindrical wick, the latter being attached to a short brass holder which is regulated by a screw. The space within the inner metallic cylinder is open both at top and bottom. When the wick is lighted it burns with a dull, wavy, smoky flame, but on suspending over it, as Argand did, a cylinder or chimney of sheet-iron, a powerful draught is excited both within and without the ring of flame, and the additional quantity of air thus brought into contact with the flame, greatly improves its brilliancy by ensuring the perfect combustion of the carbon, which without such a contrivance passes off in smoke. Soon after the original invention, Lange suggested a glass instead of an iron chimney, and altered its form by contracting the diameter of the cylinder a little above the burner. By this means the draught on entering the cylinder has its direction changed at the point where the contraction begins, and is thus thrown upon the flame in a more advantageous direction for combustion. [See CANDLE. CHIMNEY. LAMP.]

ARRIS, the intersection or line, on which two surfaces of a body forming an exterior angle meet each other. The term is used by all workmen engaged in building, as the arris of a stone, of a piece of wood, or of any other material. Although the edge of a body may in general language mean the same thing as its arris, yet, in building, the term edge is restricted to those two surfaces of a rectangular solid, on which the length and thickness may be measured, as in boards, planks, doors, shutters, and other framed joinery.

ARROW-ROOT. A very pure form of STARCH, used as food. It is obtained from the tuberous roots of several species of *Maranta*, a family of herbaceous tropical plants, of which *Maranta arundinacea* is the most esteemed, and produces the best West Indian arrow-root. This starch is more nourishing than that from wheat or potatoes, and is obtained in the following manner:—The fleshy rhizomes, or roots of the plant, are dug up when a year old, and well washed in pure water; they are then either grated or pounded in wooden mortars, and the pulpy matter to which they are reduced is then thrown into a large quantity of water, and agitated. The fibrous parts are collected in the hand, squeezed, and removed, and the remaining milky liquor is strained through a hair-sieve, and left to settle. The white pasty mass, which sinks to the bottom of the vessel, is the arrow-root, which is sometimes subjected to a further washing, and again left to subside, before it is pronounced fit for the market. It is then dried and packed for exportation. The arrow-root of Bermuda is considered the finest.

Several substitutes for arrow-root have been employed, such as *Canna starch*, or *Tous les mois*, obtained from the roots of *Canna coccinea*, extensively grown at St. Kitt's; *Otaheite arrow-root*, which is the starch of *Tacca pinnatifida*; *Portland arrow-root*, from the fleshy roots of *Arum maculatum*, which are acrid when raw, but when roasted or boiled become wholesome, and yield a starch resembling arrow-root, common in the Isle of Portland; and *East Indian arrow-root*, which is obtained from some species of *Curcuma*.

Arrow-root is prepared for use by first mixing it with a small quantity of cold water to the smooth consistency of cream; then adding boiling water, or boiling milk under constant stirring, until it becomes a uniform pasty mixture, which may be flavoured with sugar, nutmeg, and wine. A table-spoonful of arrow-root is sufficient to make a pint of this food.

ARSENIC, (ἀρσενικὸν, masculine, so called from its *masculine* force in destroying man,) resembles the metals in its physical properties, but not so in its chemical, for, instead of forming oxides with oxygen, it forms acids, in which respect it resembles phosphorus. The term arsenic, in its popular signification, is one of the oxides of the metal, namely, arsenious acid, or white arsenic. This acid combining with bases forms arseniates, many of which are native. Arsenic also occurs as a sulphuret, and is frequently found in combination with other sulphurets, as with the sulphuret of iron, forming arsenical pyrites. During the roasting of the arsenical sulphurets of copper, iron, cobalt, and nickel, abundance of white arsenic is formed, from whence the commercial demand is supplied. Traces of arsenic are to be found in many minerals and in their products, as in sulphuric and sulphurous acids, in zinc, sulphuret of antimony, &c.

Metallic arsenic may be obtained by gradually heating to redness white arsenic, with its weight of black flux,[1] in a small retort contained in a sand-bath: the metal sublimes into the neck of the retort. It is of a steel grey colour, of crystalline texture, very brittle, and of the specific gravity of about 5.8 Heated to a dull red, it sublimes without fusing, so that it would appear to be incapable of assuming the fluid state. According to Regnault, the reason for this is because the temperature at which it fuses is very near that at which it boils, under atmospheric pressure. Volatile bodies throw off vapours far below their boiling points,—a property applicable to solids as well as to liquids. Arsenic gives off abundant vapours at a temperature a little below its boiling point, and can be completely sublimed without attaining its fusing point. But the distance between the fusing point and the boiling point of a body may be indefinitely increased. The boiling point of any substance is the temperature at which the elastic force of its vapour is in equilibrium with the pressure exerted on it. By increasing this pressure the boiling point is necessarily raised; but the fusing point is

(1) Black flux is made from a mixture of 1 part nitre and 2 parts crude tartar, introduced in successive small quantities into a large earthen crucible, heated enough to cause feeble combustion. From the quantity of tartar used, this flux contains an excess of charcoal, resulting from the tartaric acid, and this frequently assists in converting metallic oxides into metals, by abstracting the oxygen.

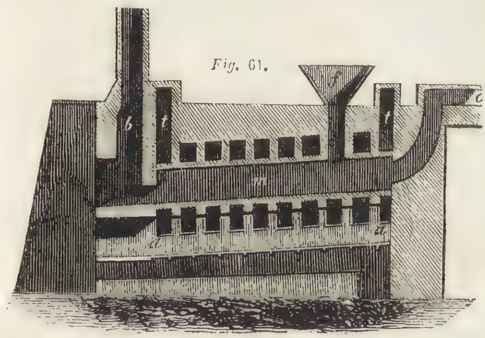
not sensibly affected. We may thus suppose that arsenic is capable of being fused, if, instead of heating it in an open tube, it is heated in a stout glass tube, hermetically sealed: the increased pressure within the tube ought to prevent the ebullition of the metal, and thus cause it to melt long before it boils.[1] Professor Brande states that the experiment has been tried, and that the tension of the vapour burst the tube before the arsenic showed signs of fusion.

Vapour of arsenic is colourless; it has an odour of garlic, which is characteristic; the density of the vapour is about 10.37. The atomic weight of arsenic is 75, and its chemical symbol As.

Arsenic combines with the oxygen of the air at ordinary temperatures; its surface tarnishes, and it becomes covered with a blackish dust; but its metallic lustre is restored by leaving it for some hours in a solution of chlorine.

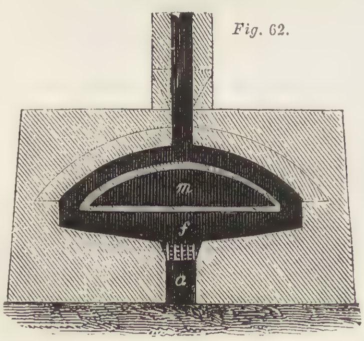
Arsenic is combustible: it burns with a livid flame, with the production of white arsenic. This substance is prepared on a large scale by decomposing, by means of heat, arsenical pyrites. In Silesia there are two mines of this ore, which supply the works at Reichenstein and Altonberg, where large quantities of metallic arsenic, arsenious acid, realgar, and orpiment, are manufactured. The ore is roasted in a muffle furnace, the sole of which *m* is somewhat inclined, as in Fig. 61.

Fig. 61.



This muffle is 10 feet long and 6 feet wide, and it has a fire, *a a*, under its whole length, the smoke of which escapes by the channels *t t* into the chimney *b*. The muffle is mounted upon brick-work, furnished with

Fig. 62.

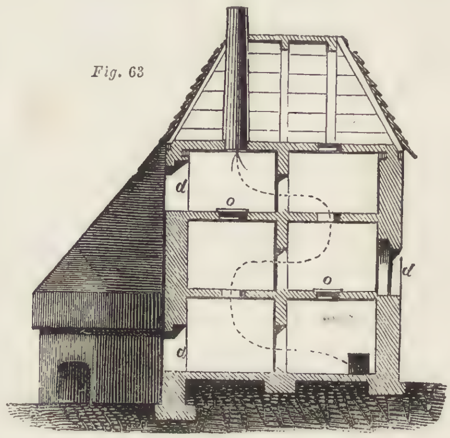


numerous openings for the flame. Fig. 62, is a transverse section of the furnace, showing the form of the muffle *m*; *f* is the fire, and *a*, the ash pit.

(1) Regnault, Cours de Chimie.

The ore is poured into the muffle by a funnel at *f*, Fig. 61, and is then spread uniformly over the sole by means of a rake. In the course of 12 hours the ore is decomposed, with the production of sulphate of iron and arsenious acid. The latter, in the form of a vapour or of a light powder, is conducted by the channel *c*, Fig. 61, into condensing-chambers, *o o*, Fig. 63, where it gradually condenses, in following the direction of the dotted line, while the heated air escapes by the flue. Every five or six weeks these

Fig. 63



chambers are cleared out, for which purpose, doors are opened at *d*, and the different chambers can be made to communicate by uncovering the openings at *o*. The purest acid is found in the lower chambers; that in the upper ones contains sulphur. The removal of the acid from these chambers is a dangerous occupation. The workmen wear a leathern dress, carefully fastened round every part of the body, and also over the head, which is further protected by a leathern helmet, furnished with glass eyelits. Under the helmet the mouth and nostrils are covered with a wet sponge or moist linen, for the purpose of filtering the air necessary for respiration.[2]

The crude arsenious acid obtained by the above process is refined by a second sublimation, in iron pots covered with drums of sheet-iron, terminating in condensing chambers. A number of these pots are placed in a furnace, and raised to a full red heat, when the acid sublimes into the drums, and forms an internal crust 2 inches thick, the exterior of which is still impure and of a brown colour, and requires to be refined a third and even a fourth time. Flowers of arsenic are condensed in the chambers.

In the treatment of certain metallic arsenio-sulphurets, the principal object is to obtain the metal which is combined with the arsenic; in this case the ore is roasted on the hearth of a reverberatory furnace, and the sulphur, which is converted into sulphurous acid, is allowed to escape up the chimney; but the

(2) Dumas, Tome Quatrième. The same excellent authority states that the health of the workmen engaged in the arsenic works requires particular care. Two small glasses of olive oil are administered to each man daily. His food consists chiefly of leguminous vegetables eaten with plenty of butter, with very little meat, but that which is eaten is very fat. Alcoholic drinks are especially to be avoided.

arsenic, which is converted into arsenious acid, is condensed in conduits placed between the furnace and the chimney.

Arsenious acid (AsO_3) when newly prepared, consists of vitreous masses perfectly colourless; but when the fragments are left some time, they become opaque, and assume the appearance of porcelain. This change proceeds gradually from the surface to the centre; for when broken, the external crust is like porcelain, while the interior is vitreous. This vitreous portion is three times more soluble in water than the opaque portion, and dissolves more rapidly. According to M. Guibourt, 100 parts of water contain in a saturated solution—

At 60° 1.25 parts of opaque acid, and 0.96 of transparent acid.
At 212° 11.47 „ „ 9.68 „

Which being left to cool during two days, is found to contain—
2.90 „ „ 1.78 „

Under the influence of cold water, the vitreous acid becomes opaque: mechanical division has the same effect, for the vitreous acid reduced to fine powder is not more soluble than the opaque.

Arsenious acid reddens litmus in the same manner as feeble acids. It has no smell at ordinary temperatures, but a pinch of it dropped upon a live charcoal exhales the characteristic smell of garlic, which arises from the metal itself, a portion of the acid being decomposed by this process. The specific gravity of arsenious acid is 3.6. It combines with bases and forms *arsenites.* The arsenious acid of commerce is used in large quantities in the preparation of green colours. Arsenite of copper is of a beautiful green colour, and forms what is called *Scheele's green:* arsenious acid is also used in medicine, in the manufacture of shot, for dissolving indigo, and in small quantities in the manufacture of flint glass, in order to get rid of the peroxide of iron in the sand, but an excess makes the glass milky. It is the common instrument of destruction in the hands of the poisoner: it is virulently poisonous when taken into the stomach, and also fatal when applied to a wound. Various antidotes have been proposed, but none seem to be effectual. When the poison has been only recently taken, the best plan is to administer an emetic, and then to give a saturated solution in acetic acid of the newly precipitated hydrated peroxide of iron, or a quantity of caustic magnesia mixed with water. These oxides, combining with the arsenious acid, form insoluble arsenites, and thus destroy the effect of the poison. Various delicate tests have been devised for detecting the presence of arsenic in food, and in the human subject after death, but these had always better be left in the hands of the scientific chemist. The poisonous properties of arsenious acid have also been taken advantage of for the destruction of vermin. To destroy mice and rats the poison should be mixed with flour or with lard, but not in too large a quantity, or these animals will not touch it. In another form the poison may be employed with advantage, in the preservation of stuffed birds and other objects in Natural History. Dumas gives the following recipe:—

White soap	100	parts
Arsenious acid	100	„
Carbonate of potassa . .	36	„
Camphor	15	„
Quick lime	12	„

The soap is to be scraped and melted in a pipkin with a little water at a gentle heat; then add the potassa and the lime, and mix them well together: the arsenious acid is afterwards added gradually and well incorporated. The camphor is reduced to powder by rubbing it up in a mortar, with the addition of a few drops of spirit of wine, and when the soap is cold, this is well mixed in. A portion of this soap mixed with water is applied to the preparation by means of a camel's hair pencil. It constantly exhales the odour of arseniuretted hydrogen, and effectually destroys insects and their eggs.

Arsenic acid (AsO_5) is obtained by distilling nitric acid off powdered metallic arsenic. The union of this acid with metallic oxides produces *arseniates.* The arseniate of potash is used in calico printing.

Arsenic combines with hydrogen, producing the volatile and highly poisonous gas, arseniuretted hydrogen. It combines also with chlorine, forming *butter of arsenic.* There are various combinations of arsenic and sulphur: one such compound, *Realgar,* occurs native, and is used in the preparation of *white Indian fire,* which consists of 24 parts saltpetre, 7 of sulphur, and 2 of realgar, finely powdered and well mixed. This composition burns with a white flame of great brilliancy. Realgar is of a beautiful orange red colour, and is used in painting. It consists of AsS_2. AsS_3, forms the yellow sulphuret or *Orpiment,* which is the basis of the pigment named *King's yellow.* Native orpiment, the *auripigmentum* of the ancients, is of a brilliant lemon or gold colour.

Arsenic unites with most of the metals, forming alloys which are generally brittle and comparatively fusible. The alloy of arsenic and iron is more brittle, harder and more fusible than iron. Iron with only 2 or 3 per cent of arsenic is very brittle when heated. Arsenic and copper form the alloy called *white tombac.*

ARTESIAN WELLS derive their name from the French province of Artois, the ancient *Artesium,* where extensive researches had for a long period been carried on for the discovery of subterranean water. In these wells the water is obtained by boring instead of digging; a method which seems to have been practised from a very early period in Italy, especially in the environs of Modena, and it does not appear to have been introduced into France until the reign of Louis XIV. It is probable that these wells were known to the ancients, for Niebuhr quotes the following passage from Olympiodorus:—"Wells are sunk in the oases from 100 and 150 to 200 feet in depth, whence water rises and flows over." Shaw also mentions a group of villages in the depth of the Sahara, which have neither springs nor fountains,

but the inhabitants sink wells to the depth of 100 or 200 fathoms.

The formation of artesian wells in our own day depends on a practical application of the science of Geology to the Useful Arts, and in order to gain a clear idea of the formation and mode of action of these wells, it is necessary to inquire into the origin of natural springs and fountains, and the conditions under which an ordinary well yields a supply of water.

By the process of evaporation which is carried on at all temperatures, water from the surface of the ocean, from lakes, rivers, and even from the ground, is raised up into the atmosphere and formed into clouds. These clouds are borne from the sea to the land, where they pour down their waters in greater or less abundance. In England the mean quantity of rain is about 31 inches; that is, nearly 3,000 tons of water are deposited in the course of the year upon every acre. A portion of this water, either derived directly from rain, or the sudden melting of snow, forms the flood waters of our rivers; a second portion evaporates from the surface of the soil, and is again taken up into the atmosphere; a third portion supplies drink and fluid nutriment to animals and plants; while a fourth portion finds its way through the pores or fissures of the soil until it reaches some bed of rock through which it cannot pass; and it is this portion which maintains the perennial supplies of wells, springs, and rivers.

It is well known that in sandy districts the rain-water penetrates as through a sieve, and even in mines which have been sunk through limestone rocks, the miners say that the water increases even in the deepest galleries within a few hours after rain has fallen above ground. Springs which issue at various elevations from the chalk cliffs of our coast, are known to be much increased in volume immediately after rain; and it is equally a matter of common observation, that in times of severe drought springs become less abundant, and many dry up altogether. Hence it will be found that springs, wells, and fountains derive all their supplies from the waters of the atmosphere, and only withhold or vary their supplies in accordance with the variation of rain, dew, snow, and evaporation.[1]

In the primary formations, such as granite, porphyry, lava, and other rocks of igneous origin, the rain waters have very limited subterranean passages, and hence each little streamlet must accomplish its course, as it were, by itself, without receiving additions from neighbouring streamlets; and accordingly, in formations of this kind the springs are very numerous and very small, and they appear very near the places where the infiltration of the rain has been effected. It is very different in the secondary formations. These have the appearance of immense basins, (Fig. 68, p. 77,) which seem originally to have been vast hori-

(1) Mr. Dickinson, the great paper-maker, who supplies the paper for stamped letter-covers, and whose mills are on one of the tributaries of the Colne, has found during many years that the quantity of water in that river during summer varies with the quantity of rain in the preceding winter. He could always tell in the end of February and March how much water there would be in these rivers in the following eight or nine months, and he regulated the contracts he made in every spring, for paper to be delivered in the summer and autumn, by the quantity of water in his winter rain-gauge. This rain-gauge, being buried 3 feet below the surface, showed, that except in December, January, and February, rain-water rarely descends more than 3 feet below the soil, so as to add anything to the supply that sinks into the earth to issue during summer, and form springs and rivers; and whenever he found by this instrument that but little rain had fallen in the three winter months, he proportionally limited his contracts for the following summer and autumn.

Fig. 64. The Emperor Fountain at Chatsworth.—*See page* 76.

zontal plains subsequently elevated, and circumscribed by the upheaving force of the primary rocks which now form their hill or mountain boundaries. These basins are arranged in layers or *strata,* some of which are of great thickness, and consist of loose and very permeable sand, and which in rising from the extremity of the basins project or *crop out* on the sides of hills and mountains; the rain-water filtering through these out-cropping strata, may form within them extended sheets of water; but when they are inclined, or *dip* at a high angle, this water rushes towards lower levels, carrying with it by degrees portions of sand, and even of the surrounding rocks, thus forming subterranean rivers which displace portions of the original massive strata, and excavating large caverns where previously there were none.

The tertiary formations are also stratified, or composed of a greater or less number of overlying beds, which, like the courses of a wall, are separated from one another by distinct and well-marked joinings. This formation, like the preceding, is usually basin-shaped, but commonly of far less extent. This shape appears to be due to some alteration in the position of the strata, during which the constituent elements of the tertiary series formed the ridges of the slopes and hills which surround them.[1] During this change in the various strata, they were all more or less violently torn, broken, and detached, so that some are exposed and crop out on the sides and summits of hills.

About two-thirds of the habitable portion of the earth consist of stratified rocks, and geological inquiries obtain much of their precision from the circumstance that the various series of strata are always arranged in a given order. In the tertiary series beds of porous sand occur at various elevations, and the surface-water first penetrates those in which the inclination is great; it then, by its lateral pressure, finds its way into the horizontal branches; so that wherever a succession of sand beds occurs resting on and alternating with impervious strata, we may also expect to find as many subterranean sheets of water.

There are many geological differences between the secondary and tertiary strata, but it will suffice for our present purpose to state, that in secondary formations all the phenomena are exhibited on a much grander scale on account of the prodigious thickness of the strata, of their less frequent alternations, and the greater velocity of the subterranean currents. Hence in the secondary formations natural springs are rare, but when they do occur they are very abundant, and form great chasms and caverns, as in the celebrated rock of Torghat in Norway, which is pierced from end to end by a rectangular opening 150 feet high, and upwards of 3,000 feet long. So, also, the cavern of Guacharo, in the valley of Caripe, in South America, has for its vestibule a vault 72 feet high by 80 feet wide, near the summit of a vast rock of secondary limestone, known as *Jura limestone.* For a length of 1,455 feet it has all the characteristics of the vestibule. The superstitious Indians would not allow Humboldt to advance further than 2,400 feet from the entrance, but he found along this extent a river 30 feet broad rolling along the floor of this magnificent cavern. In the cavern of Adelsburg in Carniola, the river Poick engulfs itself. It appears and disappears many times, and has been traced underground through an extent of 6 miles, as far as a large lake. The Fountain of Vaucluse also issues from subterranean rocks, and pours forth a volume of 13,000 cubic feet per minute, even under ordinary circumstances, and this is sometimes increased to 40,000 cubic feet. But one of the most striking examples of these subterranean sheets of water of a varying level is that of the Lake Zirknitz in Carniola. This lake is about 6 miles long, by 3 broad. Towards the middle of summer, if the season be dry, its surface falls rapidly, and in a few weeks it is completely dry. The openings by which the waters retire beneath the soil may then be seen, in some places quite vertical, in others sloping towards the caverns of the surrounding mountains. Immediately after the retreat of the waters, all the extent of the surface which they covered is put under cultivation, and at the end of a couple of months the peasants are mowing hay, or reaping millet and rye, in the very spot where, some time before, they were fishing for tench and pike. Towards the end of autumn, and after the rains of that season, the waters return by the same natural channels which had opened a passage for them at the time of their departure. This is the regular and usual course; but sometimes a very heavy fall of rain on the mountains which surround Zirknitz occasions the return of the waters to the surface at an earlier period than was expected.

But it is not in hilly and mountainous districts alone that these abundant supplies of subterranean waters are to be observed; for even in flat countries there are caverns in which whole rivers are engulfed. Thus the Guadiana loses itself in a flat country, in the midst of an immense meadow. This explains the fact that, when speaking with admiration of some superb bridge in England or France, the Spaniards remark that they have one in Estremadura upon which 100,000 head of cattle can feed at the same moment. Thus the Drôme in Normandy is lost in the midst of a meadow, in a pit about 30 feet in diameter, known as the Fosse de Soucy. In the same district of France other rivers are lost by degrees. There are from one point to another in the beds of these rivers great gaps, called *bétoirs,* each of which absorbs a portion of the stream. On its arrival at the last bétoir the stream is usually reduced to the size of a trifling rivulet.

There is often in these stratified formations distinct

[1] (1) These strata were originally deposited horizontally, but sometimes two and three deposits are found in preexisting basins bounded by older formations. These more recent beds extend horizontally until they come in contact with the older rocks, which enclose them as in a circus. The upper bed only is visible, and it alone receives directly the rain. The surface-water cannot reach the older strata except across the beds which cover it, conditions not very favourable to the formation of subterranean lakes compared with those which exist in basins the boundary ridge of which is composed of strata which have undergone the alterations noticed above.

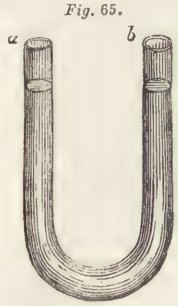
sheets of water at different depths. For example, in the works which have been undertaken in search of coal near St. Nicholas d'Aliermont, near Dieppe, seven great sheets of water were passed through; the first of which was at the depth of 76 feet; the second at 307 feet; the third at 537 feet; the fourth at 645 feet; the fifth at 768 feet; the sixth at 880 feet; and the seventh at the depth of 1,030 feet. Wells which have been sunk in the neighbourhood of London and elsewhere have illustrated the same fact.

But, in addition to these stationary sheets of water in the heart of stratified rocks, water-courses have been found, true subterranean rivers, flowing rapidly in the empty spaces which exist among the impermeable rocks. For example, in boring near the barrier of Fontainebleau, at Paris, the progress had for some time been slow and tedious, as is usually the case in such works; but suddenly the boring tool escaped from the hands of the workman, who saw it fall rapidly upwards of 20 feet, and the transverse handle at the top of the first joint of the borer prevented it from falling any further. When the men endeavoured to raise the instrument, it appeared as if a strong current was carrying it on one side, and causing it to oscillate; but the rapid ascent of the waters of this deep stream prevented further observation. At Port St. Ouen five distinct sheets of water were observed. On penetrating the third sheet, the borer sank suddenly more than a foot; and the current must have been strong, since it impressed the whole of the instrument with a very sensible oscillatory movement. When the end of the borer, filled with debris of the rocks, came, in drawing it up, to the spot where this third sheet of water was, it was not necessary to raise it further, for the current washed away the whole of the debris, an effect which could not have been produced had the water been stagnant.

It will be seen then, that on making an opening from the surface down to these subterranean waters, the water in many cases gushes up to the surface, and forms a perpetual fountain. Now, the question is, What is the power which causes these subterranean waters to rise to the surface and form a constant *jet d'eau?*

If water be poured into a tube of the shape of the letter U, Fig. 65, it assumes a level, and maintains itself in the two branches *a*, *b*, at heights which are exactly equal. Suppose the left branch of this tube to open towards the top into a large reservoir, which can maintain itself always full; and that the right branch is cut across towards its lower part, so that only a portion of its vertical part remains, and that this portion is fitted with a stop-cock; when the stop-cock is opened, the water will be projected into the air to the same height to which it would have risen had this branch remained entire. In other words, it will ascend as far as it has descended from the level of the reservoir which constantly supplies the opposite branch. In practice, the height of the jet will be somewhat less than the level of the reservoir, on account of friction, the resistance of the air, and opposing currents of ascending and descending particles; but the slight deduction which must on these accounts be made interferes in no way with the principle of fluid level which we are now considering.

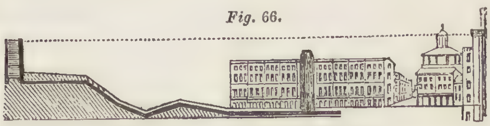
Fig. 65.



This simple experiment is realized on a grand scale in the conduit-pipes which serve to distribute the water of elevated springs or reservoirs to the different parts of a town, or in the subterranean pipes destined to produce jets d'eau in gardens and public squares. When the Romans wished to conduct water from one hill to another, they constructed in the intermediate valleys immense aqueduct bridges, such as the Pont du Gard; and they did so, as we believe, not in ignorance of the hydrostatic principle of fluid levels, but in order to obtain a far more abundant supply than could be furnished by a pipe or series of pipes. The Turks were among the first to adopt the more economical plan, of carrying metal pipes, or a brick or stone tunnel, along the intermediate valley, making it follow the different inflections it might encounter, and finally causing it to ascend the slope of the second hill. The water flowing down this pipe rises, after crossing the valley, to nearly the same height as it had descended.

Now suppose the tube to be carried only to the middle of the valley, and that a single opening on its upper side is made for its escape, the water will in such case be projected perpendicularly upwards, and this jet will rise higher in proportion as the descending current has a great fall. This is the construction of all jets d'eau. The form of the pipe in which the water is conducted is quite a matter of indifference. It may be circular or elliptical, square or polygonal, straight, and of great length, or having many windings and ramifications; and yet the water will equally rise to the height nearly of the level of the reservoir, whenever it has free course to obey the pressure to which it is subjected. Fig. 66 is a section of the reservoir or head of water at New York used for distributing the water of the Croton Aqueduct over the city. (AQUEDUCT.) It will be seen that this reservoir is situated above the level of the houses, and the pipe commencing at its base, being conducted into one of the public squares of the city, forms a beautiful jet d'eau, which rises nearly to the level of the water in the reservoir.

Fig. 66.



Distributing Reservoir. *Union-square.*

Some of the most remarkable ornamental jets d'eau are constructed on this principle. That at Versailles rises to the height of 90 feet; the old fountain at Chatsworth rose to the height of 94 feet; that of Peterhoff, in Russia, 120 feet; that at St. Cloud 160

feet; that at Wilhelmshöhe, in Hesse Cassel, 190 feet, but this fountain is now out of order. The most remarkable fountain in the world is probably the Emperor Fountain at Chatsworth, so named by the Duke of Devonshire in honour of the visit of the Emperor of Russia to this country, a few years ago. This fountain plays to the height of 267 feet; and it is expected, when the reservoir is quite full, to raise it to the height of 280 feet. Fig. 64 (p. 73) represents this fountain in action. For the purpose of supplying it, a new reservoir was constructed, and a conduit or drain cut to convey water into it. This drain commences at Humberley Brook, near one of the bridges on the Chesterfield road, and is increased by tributary springs from the moors, passing along with a gentle fall to the reservoir, for two miles and a half, and winding round a hill in serpentine forms to the proper level. The reservoir covers eight acres of ground; its average depth is about 7 feet; its greatest depth at the head is 13 feet, where there is a solid mass of masonry with a deep valve, to let the water off and on. There is also a waste-pipe for the surplus water. The first length of piping from the reservoir towards the fountain is on the top of the hill, where the ground is comparatively level: this length is 270 feet; the pipe is of 15-inch bore, and the metal three-quarters of an inch thick. The middle length is 1,386 feet; 15-inch bore, and 1 inch metal. The lower length is 959 feet; 15-inch bore, and $1\frac{1}{4}$ inch metal: making altogether 2,621 feet, or 873 yards, 2 feet. At the distance of 181 feet from the fountain is a double-acting valve, which takes about five minutes to open or shut fairly, so that the whole may never be let on or off with a shock to the pipes. For a short distance from the fountain the pipe is $1\frac{1}{2}$ inch thick in the metal, and is secured by a saddle-plate and bracket cast solid to the pipe, and is firmly bolted to a mass of masonry. The end of this large pipe turns up with an elbow, and terminates with a flange, to which the conical tapering part of the jet is fixed. This conical part is about 7 feet high, and terminates in a brass nozzle. Different funnels and nozzles are used, to give variety to the form of the water jet. There are 298 joints in the piping, turned and bored with dip sockets round each, and the weight of the metal in the pipes is about 217 tons. The whole fall of pipe from the reservoir to the fountain is 381 feet, but not of uniform declivity; for the first 450 feet the fall is 1 in 40; for the next 200 feet the fall is very steep, it being 1 in 2; for the next 800 feet it is 1 in 5; and for the remainder 1 in 9.

Bearing in mind the simple but important principle upon which artificial fountains depend, the reader will understand the mode of formation in natural fountains. It is only on the slopes of hills or at their summits that the beds of the stratified series of rocks crop out or are exposed on edge; here it is that the rain-water penetrates and fills the elevated mountain cisterns or hilly reservoirs: these water-carrying beds, after having descended along the sides of the hills, which formerly broke them up while they elevated them, extend horizontally or nearly so along the plains, and in the plains they are often imprisoned as it were between two impermeable or water-tight beds of clay or of hard rock; and thus we may readily conceive the occurrence of subterranean waters in the same hydrostatic condition as the pipes of the fountains just noticed, so that by sinking a pit in the valleys through the upper strata down to the more elevated of the two impermeable beds, between which the water is confined, we thus provide as it were the second branch of pipe, in the form of the U already noticed, or the jet of the fountain at Chatsworth, and the water will rise in this pipe or jet to a height corresponding to that which the water maintains on the side of the hill when it begins to descend. Hence, in any horizontal plane, the different subterranean waters at different elevations may have different powers of ascending: in one place the same water may be projected to a great height, and in another rise no higher than the surface of the soil. All the variations which are met with, arise simply from inequalities of level.

But some of these natural fountains, such as those of Lillers in Artois, throw up their waters in the midst of immense plains, where no hill, not even a hillock, is to be seen in any direction. In such a case, the hydrostatic columns are to be sought for some miles off, hundreds if necessary. The existence of a watery subterranean communication 300 miles in extent, is no objection when 300 miles of country have the same geological constitution. Even at the bottom of the ocean, springs of fresh water project vertically to the very surface. This water evidently proceeds from the land by natural channels, which rise higher than the surface of the sea. On one occasion when Buchanan was becalmed in the Indian ocean, he discovered an abundant spring of fresh water, at the distance of 125 miles from Chittagong, and 100 miles from the neighbouring coast of the Sunderbunds.

These remarks will receive further illustration from the following diagram, Fig. 67. Suppose a basin, composed of permeable strata E F G alternating with impermeable strata H I K L, to have the margin of all these strata continuous in all directions at one uniformly horizontal level A B; the water which falls in rain upon the extremities of the strata E F G, would accumulate within them, and fill all their interstices with water, up to the line A B; and if a pipe were passed down through the upper into either of the lower strata, at any point within the circumference of this basin, the water would rise within it to the

Fig. 67

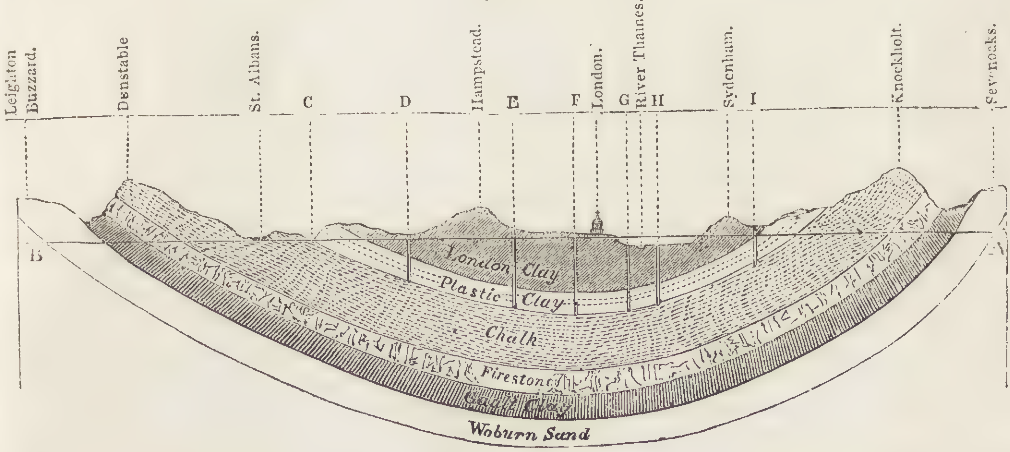
horizontal line A B, which represents the general level of the margin of the basin. A disposition so

regular never exists in nature; the extremities or outcrops of each stratum are usually at different levels, *a, c, e, g*. In such cases the line *a b* represents the water-level within the stratum G; below this line, water would be permanently present in G; it could never rise above it, for it would be relieved by springs that would overflow at *a*. The line *c d* represents the level above which the water could never rise in the stratum F; and the line *e f* represents the highest water level within the stratum E, the discharge of all rain waters that percolated the strata EFG, being thus effected by overflowing at *e, c, a*. If common wells were sunk from the surface *ikl*, into the strata GFE, the water would rise within them only to the horizontal lines *ab, cd, ef*. The upper porous stratum C, also, would be permanently loaded with water below the horizontal line *g h*, and permanently dry above it.

The following section is intended to explain the rise of water in artesian wells in the London basin, from permeable strata in the plastic clay formation and subjacent chalk. The water in all these strata, as already explained, is derived from the rain which falls on those portions of their surface that are not covered by the London clay, and is upheld by clay beds of the gault beneath the chalk and fire-stone. Thus admitted and sustained, it accumulates in the joints and crevices of these strata, to the line BA, at which it overflows by springs, in valleys, such as that represented at C. Below this line all the permeable strata must be permanently filled with a subterranean sheet of water, except where faults or other disturbing causes afford local sources of relief. Where such do not interfere, the horizontal line B A represents the level to which water would rise by hydrostatic pressure in any perforations through the London clay, either into sandy beds of the plastic clay formation, or into the chalk; such as those represented at DEFGHI. If the perforation be made at G or H, where the surface of the country is below the line BA, the water will rise in a perpetually flowing artesian fountain, as it does in the valley of the Thames between Brentford and London.

In proportion as the number of Artesian wells is increased, the height to which the water ascends in each becomes diminished, and the general application of them would discharge the subterranean water so much more rapidly than it arises through the interstices of the chalk, that fountains of this kind would soon cease to overflow, although the water within them would rise and maintain its level at the surface of the land. At Brentford there are many wells which continually overflow their orifices, which are only a few feet above the level of the Thames. In

Fig. 68.

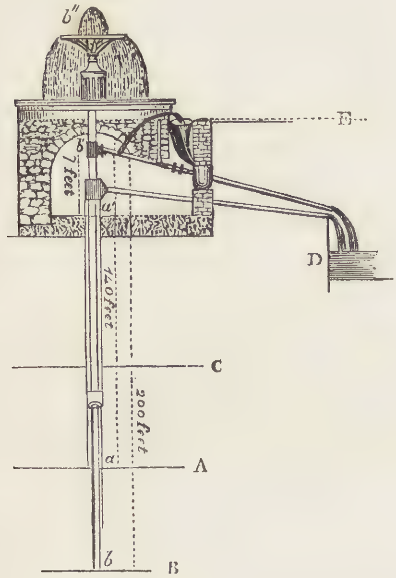


the London wells, the water rises to a less level than in those at Brentford, and it is by no means certain that an adequate supply of water for the whole of London could be obtained by boring, as has been proposed. The water which supplies the fountains of Trafalgar Square, rises only to within about 16 feet of the surface, and it is pumped up by a steam engine, into reservoirs at the back of the National Gallery. After supplying the fountains, the water goes to supply some of the public offices in the neighbourhood of the Horse Guards, and the remainder is returned into a reservoir connected with the steam engine, so that it can be pumped up and used a second time if necessary.

The mode of action of an Artesian well will be understood from the section, Fig. 69, representing a double fountain at St. Ouen, which brings up water from two water-bearing strata at different levels below the surface of the soil E. In this double fountain the ascending forces of the water in the two strata A and B are different; the water from the lower stratum B, rising to the highest level b''; that from the upper stratum A, rising only to a'. The water from both strata is thus brought to the surface by one bore hole, of sufficient size to contain a double pipe, viz. a smaller pipe included within the larger one, with an interval between them for the passage of water; thus, the smaller pipe *b*, brings up the water of the lower stratum B, to the highest level of the fountain b''; whilst the larger pipe *a*, brings up water from

stratum A to the lower level a'. Both these streams are employed to supply the canal-basin D at St. Ouen, above the level of the Seine. Should the lower stratum B contain pure water, and that in the upper strata A C be tainted, the pure water might by this apparatus be brought to the surface through the impure, without contact or contamination.

Fig. 69.



But where a single pipe is used, as is generally the case, if the boring penetrates a bed containing impure water, it is continued deeper until it arrives at another stratum containing pure water; the bottom of the pipe being plunged into this pure water, it ascends within it, and is conducted to the surface through whatever impurities may exist in the superior strata. The impure water is excluded by the pipe from mixing with the pure water ascending from below.

One of the most remarkable Artesian wells of our own time is that of Grenelle, in the Paris basin. It was undertaken in 1834, up to which time no successful artesian sinking had reached a greater depth than about 1,000 feet. It was calculated that after passing through the tertiary beds, and the chalk, the upper greensand would be reached at a depth of 1,200 or 1,500 feet. Operations were commenced with an auger of unusual dimensions, viz. 1 foot in diameter; the borings brought up, in succession, the alluvial soil and subsoil, and the tertiary sands, gravels, clays, lignite, &c., until the chalk was reached. They then bored through the hard upper chalk down to the lower chalk with green grains; the dimensions of the auger being reduced at 500 feet to 9 inches in diameter; at 1,100 feet, to 7½ inches; and at 1,300 feet, to 6 inches in diameter. In the course of these borings, numerous accidents occurred. In May, 1837, at the depth of 418 yards, the hollow tube with nearly 90 yards of the boring rods attached to it broke, and fell to the bottom of the hole, and fifteen months were occupied in extracting the broken fragments, of course delaying the work for that period. In April, 1840, in passing through the chalk, the chisel attached to the boring-rod fell off, and several months were occupied in recovering it. A similar accident occurred a second time, but instead of attempting to recover it, it was driven into the stratum, which happened to be gravel. When the calculated depth of 1,500 feet had been reached without any result, the Government became disheartened, and the public patience exhausted. On the urgent representation of M. Arago, the sinkings were continued, until at length, on the 26th of February, 1841, the rod suddenly descended several yards. They had pierced the vault of the subterranean waters, and in the course of a few hours the water rushed up violently from a depth of 1,800 feet. The first rush brought up an immense volume of water mixed with sand and mud, and at a high temperature. It rose many feet above the surface, and the force was so great that considerable injury was done to the boring rods, and it was some time before the shaft could be sufficiently cleared for the full discharge to issue without interruption. The pipe by which the water reached the surface was carried to a height nearly on a level with the source of the supply. The pipe as it rose from the ground, and the scaffolding which supported it, are shown in Fig. 70, where the water is represented flowing into a circular iron reservoir, from which it was conveyed by

another pipe to the ground. Since the tubes have been completed, about half a million of gallons of perfectly limpid water have been supplied by this well in the course of the twenty-four hours, at the constant temperature of 82° Fahr.

The temperature of the water of Artesian wells is always higher than that of the surface, according to Arago, in the ratio of 2° for every 60 or 80 feet of

descent; but according to the observations of Dr. Paterson on eleven Artesian wells in Scotland, the mean increase is 1° for every 48 feet of descent; and the mean of seventeen wells in other places gave 1° for every 53 feet of descent. In one observation the temperature of the well water was 52°, while that of the surface of a spring close by was at the freezing point.

Artesian wells have been sunk to various depths. The greatest depth is that of Grenelle just noticed. The seventh sheet of water found near St. Nicholas d'Aliermont already alluded to, was at the depth of 1,030 feet, and the water rose from it to the surface. As it was not water but coal that was sought for the works were abandoned, but a copious fountain was unintentionally formed, the waters of which issue from a source more than 1,000 feet deep. In the Duke of Northumberland's grounds, at Syon, is an Artesian boring 535 feet deep. The borings passed first through loose gravel and sand, and strong blue clay, to the depth of 410 feet; then through 10 feet of green sand; next through 30 or 40 feet of loose chalk; and lastly into firm, hard chalk. This well rises 5 feet above the surface.[1]

As to the quantity of water from Artesian wells, the supply appears to be in most cases continuous and abundant. In the monastery of St. André, two miles from Aire, in Artois, a fountain has continued for considerably more than a century to rise to the height of 11 feet above ground, and to supply nearly 2 tons of water per minute. At Bages, near Perpignan, is a well which furnishes 333 gallons per minute. One at Tours jets 6 feet above ground, and yields 237 gallons per minute;[2] and at Merton in Surrey is a well which supplies 200 gallons per minute. At Southampton there is an Artesian well which overflows to the height of 5 feet, and yields 10 gallons per minute. At the depth of 100 feet, it supplies to the pumps 48 gallons per minute. The water is from the sandy stratum in the tertiary formations that overlie the chalk which forms the foundation of the geological basin in which Southampton stands. At Brighton, in 1842, a well bored in the chalk to the depth of only 97 feet, gave by pumping with steam, 700 gallons of water per minute. In some cases, the supply of water has been so abundant as to lead to inconvenience. Thus, a case is mentioned in the *Bibliothèque Universelle de Genève*, of an Artesian boring in a garden to the depth of 360 feet, and 4.5 inches in diameter, in which the first discharge of water was so copious as to overflow the whole yard round the house, and to submerge the adjacent cellars. The damage was so great that the neighbours lodged a complaint, and the police interfered. Two or three men attempted to close the bore with a wooden and afterwards with an iron plug, but they were driven back by the violence of the water. A mason then planted several tubes of small diameter over the bore, and thus succeeded in mastering the water.

Artesian wells have not only been employed for providing houses with water, but their waters have also been used as a moving power. In the village of Gonéhem near Bethune, there are 4 borings to the depth of 120 feet: the waters are conveyed into the watercourse of a flour mill, and are also made to subserve other agricultural purposes. The little town of Roubaix near Arras, was in danger of losing its principal means of support, viz. its silk spinning and dye works, from want of water. Artesian wells were sunk, one of which yields 288 cubic yards of water per day, or double the power of a steam engine of 20 horse power. At Tours, an Artesian well pours 237 gallons of water per minute into the trough of a water-wheel 21 feet in diameter, which is the moving power of a large silk manufactory. In another case, at Fontès near Aire, the united waters of 10 wells are made to turn the mill-stones of a large mill, to blow the bellows and to beat the hammers of a nail manufactory.

The constant high temperature of these waters renders them especially valuable during winter, either as a moving power or as a means of thawing and washing away the ice which impedes the motion of water-wheels in time of frost. In Wurtemburg, the water of several Artesian wells is transmitted through metal pipes arranged in large manufactories, and thus a constant temperature of 47° is maintained at a season when the external temperature is at zero. Green-houses have been heated in a similar manner, and the Artesian waters of Grenelle have been applied as a source of warmth to hospitals and other public buildings. By introducing the water of Artesian wells into fish-ponds, the extreme variations of the seasons have been prevented. Artificial cress plots have also been formed and supplied by means of these wells with pure water of a steady temperature. The artificial cress plots of Erfurt produce a large annual revenue. Paper mills have also been supplied with the pure water of these wells at periods when heavy rains have made the river water muddy. In the Department du Nord the fine line used in the manufacture of cambric, lawn, lace, &c., is prepared from flax retted in pools which are supplied by Artesian waters: by their purity and invariable temperature, the soluble portions of the flax are more quickly removed and the valuable qualities of the filaments retained in high perfection.

Such are a few of the advantages and practical applications of Artesian wells. They are most available and of the greatest use for domestic purposes in low and level districts, where water cannot be obtained from superficial springs, or by wells of ordinary depth. Artesian borings called *Blow-wells* have long been known on the east coast of Lincolnshire, in the low chalk district between the wolds of chalk, near

(1) One of the first Artesian wells near London was bored in 1794, at Norland House, on the north-west of Holland House. The water was obtained from the sandy strata of the plastic clay formation, but so much obstruction accompanied the admission of water to the pipes from this formation, that it was found more convenient to pass lower down through these sandy strata, and obtain the water from the subjacent chalk.

(2) The water from these wells rushes up with so much force, that a cannon ball placed in the pipe is violently ejected by the ascending stream.

Louth and the Wash. These districts were without springs until it was discovered that by boring through the clay to the subjacent chalk, a fountain might be obtained which would flow incessantly to the height of several feet above the surface. It has even been supposed that by means of Artesian borings, water may be raised to the surface in the sandy deserts of Africa and Asia; and it is in contemplation to construct a series of these wells along the main road which crosses the Isthmus of Suez.

But if Artesian borings have been in the majority of cases successful, it must not be forgotten that failures do sometimes occur. Thus at Blingel in the valley of Ternoise, three borings were made in 1820; the first became a very beautiful projecting fountain; the other two, very near to the first, gave no water. At Bêthune, a boring after having pierced 70 feet of alluvial soil and 30 feet of limestone, brought to the surface a beautiful limpid jet of water. In the garden of the contiguous property, a similar operation of boring produced no water even though the chalk had been penetrated more than 100 feet.

Such cases as these are by no means rare; and M. Arago explains these failures in the following manner:—It must be remembered that these subterranean waters do not form sheets of great extent, and even do not form sheets at all, except at the surface of separation of two distinct mineral beds. On the contrary, in the thickness of those of the beds which are least compact, as in the case of chalk, the water neither exists in any certain defined limits, nor circulates except in trenches between which are found masses of chalk without fissures and hence impermeable. If the bore enters one of these trenches, water will gush up more or less according to the pressure it there sustains; but should the boring be carried on in a very compact portion of chalk, the labour will be lost. If however the bore be carried to the impermeable bed upon which this mass rests, then there would be found not only streamlets and liquid trenches but a plentiful reservoir, and the success of the operation would be complete.

Artesian wells are sometimes curiously affected by the tides. In the Artesian well of the palace of the Bishop of London at Fulham, which is bored to the depth of about 300 feet, the quantity of water is 80 or 60 gallons per minute, according as the tide is high or low. M. Arago explains the effect in cases of this kind, by supposing the subterranean river which feeds the well, also partially to discharge itself into the sea or into a tidal river by an opening of considerable dimensions compared with its own size. If this opening be diminished the pressure will immediately increase at all points of the natural or artificial channels occupied by the subterranean waters, and the flow by the well will become more rapid, or what is the same thing, the level of the water will rise. The flow of the rising tide immediately above the opening by which the subterranean waters discharge themselves, will increase the pressure upon the opening, the effect of which will be similar to that of diminishing its size, so that a less quantity of water will escape into the tidal river. When, on the contrary, the tide is ebbing, the pressure will be diminished and an increased quantity of water will flow from the subterranean courses. Hence it will be readily seen that the flowing and ebbing of the tide must produce a corresponding flowing and ebbing of the water of the well.

There is a description of boring or sinking which M. Arago terms *negative Artesian wells* or *drain-wells.* These are pits sunk for the purpose of transmitting into the earth, water retained at the surface by strata of impermeable clay or stone, thereby rendering extensive districts mere morasses unfit for cultivation. Thus the Plain of Paluns near Marseilles was formerly a great morass which it appeared impossible to drain by surface channels. King René sunk numerous drain-wells which proved effectual, and the waters thus carried off are said to have formed the projecting fountains of the port of Mion near Cassis. The river Orbe in the Jura which descends from the lake of the Rousses, conveys into lake Joux much more water than is removed from it by evaporation. This latter lake, which has no river issuing from it, nevertheless maintains a nearly uniform elevation. "It is," says Saussure, "because nature has provided for these waters subterranean issues by which they are engulfed and disappear. As it is of the greatest consequence for the inhabitants of this valley to preserve these natural drains, without which their arable lands and habitations would be immediately overflowed, they preserve them with the greatest possible care; and when they perceive that they do not take off the water with sufficient velocity, they themselves open new ones. For which purpose all that is necessary is to sink a pit 15 or 20 feet deep, and about 10 feet in diameter in the thin and vertical strata, the summits of which appear on the surface. The waters absorbed by these *entonnoirs,* or funnels, as they are called, are observed to rise from the earth and form a large spring, called Orbe, at the distance of two miles below the southern extremity of the lake." In this passage of two miles the absorbed waters descend 680 feet.

In the winter of 1832-3 a manufacturer of potato-starch at Villetaneuse, a small village about three miles from St. Denis, sunk a pit to the depth of the absorbing stratified beds, and thus got rid of no less than 16,000 gallons of impure water per day, the stench of which had given rise to serious complaints which would probably have compelled him to break up his establishment. After six months of daily absorption, nothing but sand was found at the bottom of the pit, so completely had the nuisance been removed by this means. It is to be feared, however, that the water of neighbouring wells might be injured.

The mechanical details connected with the formation of Artesian Wells, will be found under BORING. Numerous sources of information have been referred to in the preparation of this article but the editor wishes specially to acknowledge M. Arago's notice in the *Annuaire* for the year 1835, and Dr. Buckland's *Bridgewater Treatise.* The method of sinking common wells will be found under the article WELLS.

ASBESTUS. AMIANTHUS. A mineral substance in which long capillary crystals are arranged in a fibrous mass. Several varieties of hornblende are of this kind, the most beautiful being the flax-like variety, called Amianthus, or mountain-flax. The term Asbestus signifies *indestructible*, while Amianthus means *unstained*, in allusion to the fact that this mineral is neither destroyed nor sullied by passing through fire. Veins of Asbestus occur in serpentine in Cornwall, and in micaceous slate at Glenelg in Inverness. In Upper Saxony, Silesia and Switzerland, Asbestus is found in veins of serpentine; in Bohemia, in metalliferous beds, accompanying magnetic iron-stone; in Dauphiny, in gneiss and mica slate.

The long and silky fibres of Amianthus have been woven into a fire-proof cloth, which in the mass is capable of resisting flame, though a single fibre would soon be reduced to a white enamel. The ancients were acquainted with the art of making this indestructible cloth, and used it to wrap the bodies of the illustrious dead on the funeral pile, that their ashes might not mix with the ashes of the wood. In the year 1702, an asbestus shroud, containing ashes and burnt bones, was discovered in the Vatican at Rome. The scarcity and high price of this material caused its use to be confined to the richest families. It is said that Charlemagne had a tablecloth of amianthus, which he would sometimes throw into the fire, after dinner, to the great astonishment of his guests. Pliny says, that napkins made of this substance were better cleansed by throwing them into the fire than by washing. By the help of gloves made of asbestus, or amianthus, red-hot iron may be safely handled, or the hand may be placed in the midst of flames with impunity. Advantage has been taken of this circumstance, not only to perform various clever tricks, but for the more important purpose of saving human life. The art of making fire-proof cloth was revived by the Chevalier Aldini of Milan, and by him applied to protective uses. It was he who arranged and contrived the fire-proof dress, which enabled its wearer to walk amidst the flames unhurt. Clothing several firemen with these dresses, he caused them to go through various experiments to prove the efficacy of the apparatus, and to inspire them with confidence. They carried bars of red-hot iron, walked over iron-gratings through which the flame of fagots ascended, or plunged their heads into a fire of shavings, kept burning in a large raised chafing-dish. The firemen's dress, as invented by Aldini, consisted of cap, gloves, and stockings of asbestus cloth, while the body was covered with strong cloth steeped in a solution of alum. Outside this was a metallic dress of iron-wire gauze, with a casque or cap, and a mask for the face. The asbestus cap, likewise, covered the face down to the neck, having suitable perforations for the eyes, nose and mouth.

The art of weaving amianthine cloth was anciently accomplished by weaving fibres of flax with those of amianthus, and then passing the cloth through a furnace, by which means the flax was destroyed, while the fire-proof material remained; but Aldini contrived to weave a much stronger cloth without the aid of any foreign substance. The fibres are prevented from breaking by the action of steam, the cloth is made loose in fabric, and the threads are about the fiftieth of an inch in diameter.

ASHLAR. A term applied by builders to the common or free-stones of various sizes as they come from the quarry. This term is also applied to the facing of thin squared stones on the brick and rubble walls of buildings. When the work is smoothed or rubbed so as to take out the marks of the tools by which the stones were cut, it is called *plane ashlar;* most of the public buildings of London, in which stone is used, are treated in this way. When the surface is wrought in a regular manner, like parallel flutes placed perpendicularly, it is called *tooled ashlar*, and is chiefly used in the basements of buildings, but when the surfaces of the stones are cut with a broad tool without much regularity, the work is said to be *random tooled;* when wrought with a narrow tool, it is said to be *chiselled* or *boasted;* if the tools be very narrow, the ashlar is said to be *pointed;* when the stones project from the joints, the ashlar is said to be *rusticated;* in this kind the faces may have either a smooth or a broken surface. According to Mr. Nicholson,[1] neither pointed, chiselled, nor random-tooled ashlar are employed in good work; in some parts of the country *herring-bone* ashlar, and *herring-bone ramdom-tooled* ashlar are used. The act of bedding the ashlar-facing in mortar, is called *ashlaring.*

ASHLARING, in carpentry, is the fixing of short upright quarterings between the rafters and the floor in garrets, in order to make more convenient rooms by cutting off the acute angles at the bottom. The triangular spaces on the sides are either left unoccupied or formed into cupboards or closets. Most of the garrets in London are built in this way.

ASPHALTUM or native bitumen, pit coal, lignite or brown coal, petroleum or rock oil, naphtha and a few other substances, are now regarded as products of the decomposition of organic, and especially vegetable matter, beneath the surface of the earth, in situations where water is present but atmospheric air is almost entirely excluded. Being deposited at the bottom of seas, lakes or rivers, and subsequently covered up by accumulations of clay and sand, the organic substances undergo a kind of fermentation, by which the above-named bodies are slowly produced. [See Coal.]—The true bitumens, of which there are a large number, seem to have been produced from coal or lignite by the action of subterranean heat. [Bitumen.] Asphaltum is also called *mineral pitch, Jew's pitch, compact bitumen* and *maltha.* It is found in considerable quantities on the shores of the Dead Sea, or *Lacus Asphaltites*, where it is called by the Arabs *Hajar Mousa* or *Moses' stone.* There is a thick bed of asphaltum at Arlona in Albania. It also occurs at Coxitambo near Cuenca in South America. It

(1) "Architectural Dictionary," by Peter Nicholson, Architect. London. 1819.

abounds also in the West India islands of Barbadoes and Trinidad. In the latter island it forms a lake or rather plain, known by the name of the *Tar Lake*, called by the French *Le Brai*, from its resemblance to and answering the purpose of ship pitch. It lies in the leeward side of the island, on a point of land which extends into the sea about two miles. This cape or headland is about 50 feet above the level of the sea. From the sea it appears a mass of black vitrified rocks, but on closer examination is found to consist of bituminous scoriæ, vitrified sand, and earth cemented together. In some parts, beds of cinders only are found. In approaching it there is a strong sulphurous smell, which is prevalent in many parts of the ground 8 or 10 miles from it. The bituminous plain is separated from the sea by a margin of wood that surrounds it. From its colour and even surface, it appears like a lake of water, and in hot and dry weather, its surface to the depth of an inch is liquid, and so cohesive that no one can walk upon it. It is circular in form and about 3 miles in circumference. On first approaching it, it has the appearance of a plane as smooth as glass, but a nearer inspection shows it to be broken up by numerous cracks and fissures, resembling the markings on the back of a turtle, which being sometimes filled with water, make the whole surface appear level. The bitumen resembles pit coal in consistence and appearance, only its colour is rather more grey. It breaks into small fragments of a cellular appearance, and glossy, with a number of minute shining particles interspersed through its substance; it is very friable, and when liquid is of a jet black colour. Some parts of the surface are covered with a thin brittle scoria a little elevated. Mr. Anderson, who describes this lake,[1] could form no idea as to its depth, for in no part could he find a substratum of any other substance, and although the smell of sulphur was strong, no appearance of that substance was to be detected. The general odour, however, was that of pitch. No impression could be made on the surface without an axe; at the depth of a foot it was a little softer, with an oily appearance, in small cells. A small portion held in a flame hisses and cracks like nitre, emitting minute sparks with a vivid flame. A piece put into the fire boils up a long time without suffering much diminution; a thin scoria then forms over the surface, under which the rest remains liquid. The absorption of heat by the black mass of the lake is so great, that the rain-water is evaporated from it very quickly. The bitumen is much used for ships' bottoms, and is said to kill the Borer or Teredo, which is so destructive to ships in that part of the world.

In many parts of the woods this substance is found in a liquid state: it smells stronger of tar than when indurated, and adheres strongly to anything that it touches. This liquid substance is *petroleum* or naphtha, holding asphaltum in solution. It is found in various parts of Europe, but most abundantly in the Birman Empire. "The town of Rainanghong is the centre of a small district, in which there are some hundred petroleum wells in full activity. The district in which they are situated consists of a sandy loam, resting upon alternate strata of sandstone and indurated clay: under these is a layer of pale blue argillaceous schistus, impregnated with petroleum of considerable thickness, and resting upon coal. The petroleum flows into the well when it is sunk a few feet into the schistus, and when it begins to fail, the well is deepened. It is remarkable that no water ever penetrates into these wells. The annual quantity of petroleum produced by the district, exceeds 400,000 hhds. The uses of petroleum where it abounds are very important: it serves the lower classes instead of oil for lamps, and when mixed with earth or ashes it answers the purpose of fuel. A composition of petroleum and resin is an excellent material for covering wood-work, and paying the bottoms of ships and boats, as it protects the timber from the attacks of insects and worms. When rectified by distillation it affords naphtha.[2]

Asphaltum varies considerably in purity, according to the quantity of different earthy substances mingled with it. When nearly pure its colour is almost black or dark brown, and it does not soil the fingers. When rubbed, it gives off a pitchy odour. Its specific gravity varies with its purity, from about 1 to 1.10. It is insoluble in water; but alcohol takes from it about 5 per cent. of a yellow resin, and ether dissolves it to the extent of about 70 per cent. Asphaltum is very inflammable: it burns with a red smoky flame, and consists principally of a substance which M. Boussingault names *asphaltene*, composed of $C_{20}H_{16}O_3$.

A few years ago, as M. Dumas remarks, asphaltum produced an industrial fever, unparalleled in the annals of the useful arts. Its valuable properties were strongly exaggerated, and it was applied to uses for which it was evidently unfitted. Repeated failures led to a reaction, and asphaltum soon fell into a neglect as unmerited as the previous high degree of favour with which it was regarded.

During this period of excitement, several companies were formed in England, for the purpose of making asphaltum roads and pavements, for paving terraces, railway platforms, kitchens and stables, for roofing, and for protecting buildings from damp. In 1837, Mr. Claridge obtained a patent for the peculiar application to these purposes of the asphaltum from Seyssel on the Rhone, in the department de l'Ain, and also published a pamphlet entitled "Instructions for the use of the Seyssel Asphaltic Mastic," from which the following particulars are derived.

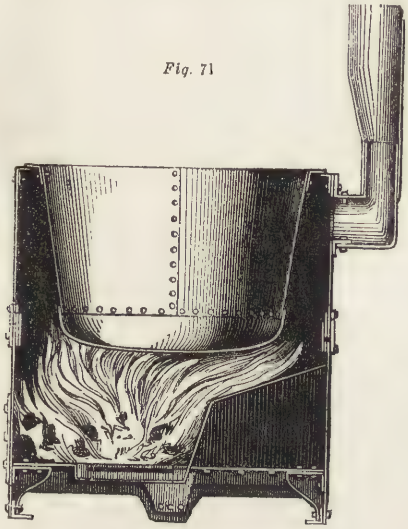
The principal ingredient in this mastic is a dark brown bituminous limestone, found near the Jura Mountains. The stone is reduced to powder and mixed with a portion of mineral tar when intended to be applied as a cement, as in covering roofs, lining tanks, &c.; but when intended to be used for flooring and for pavements, sea grit is used in addition. The

(1) "Philosophical Transactions of the Royal Society," Vol. LXXIX.

(2) Cox: "Asiatic Researches." Aikin: "Dictionary of Chemistry."

ingredients are exposed for some hours to a strong heat in large caldrons, and kept constantly stirred by machinery. The mastic thus formed, is run into moulds about 18 inches square by 6 inches deep, and formed into blocks, weighing from 112lbs. to 130lbs. each. In this state it is sold for use, but it requires to be re-melted on the spot where it is to be applied, for which purpose, small portable furnaces and caldrons, Fig. 71, are provided. 1lb. of mineral tar is first

Fig. 71



put into the caldron, and when this is melted, 56lbs. of the mastic are added, the whole being stirred repeatedly with a curved loop of iron attached to a handle, Fig. 72, so as to detach any portions of the mastic from the sides and bottom of the vessel and prevent burning. When the contents are properly melted, the caldron is covered up for a quarter of an hour, after which another 56lbs. of mastic are stirred in. The caldron is again covered for a short time, and additional quantities of tar and mastic are added in the proportion of 1lb. of the former to 1 cwt. of the latter, until the caldron is full. When the whole is completely melted and fit for use, jets of light smoke will proceed from the mixture, and the mastic will drop freely from the stirrer. The only kind of tar to be used in this mixture, is that with which the limestone is impregnated. If the mastic is required to be very stiff, as for paving kitchen floors, a smaller proportion of tar is to be used. In such cases, also, a larger proportion of grit is mixed with the mastic, and when it is desired to convert fine asphalte into coarse, 30lbs. of fine clean grit are to be added to 112lbs. of mastic, with from 1lb. to $2\frac{1}{2}$lbs. of tar.

Fig. 72.

When the melting is complete, the mastic is conveyed quickly to the spot where it is intended to be used, either in iron ladles or heated iron buckets. The caldron ought to be as close to the work as possible, and in covering brick arches or arched roofs it may be hoisted to the top of the building; taking care, however, to protect the finished part from the heat of the furnace by a layer of sand or bricks.

In forming foot or carriage roads, it is important to secure a good foundation, either by removing or ramming the soft earth and laying a coarse concrete,

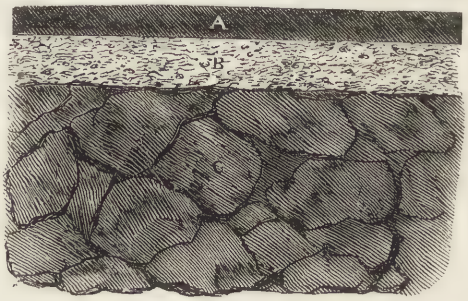


Fig. 73.

C, Fig. 73, formed by mixing 7 parts clear river sand or gravel, and 1 part fresh grey-stone lime in powder. The quantity of water should be only just sufficient to moisten the mass, which must be immediately levelled and rammed solid. The hollows must then be filled up with a finer concrete, B, and the whole be allowed to dry before laying the asphaltum. Unless this precaution be attended to, the heat will convert the moisture of the concrete into vapour, and fill the asphaltum with air holes. This may to a great extent be prevented by sifting fine cinder dust over the concrete, and in rainy weather if the work cannot be protected by a tarpaulin, sheets of tarred brown paper may be spread over the concrete and the asphaltum be poured over these. The thickness of the layer of asphaltum, A, is regulated by slips of wood, arranged so as to divide the pavement into compartments not exceeding 30 inches wide, when only one workmen or spreader is employed, but double that size when two spreaders are engaged. The work is levelled by a curved wooden spatula assisted by a floating rule or long straight ruler, stretching across the layer of asphaltum, over which it is moved backwards and forwards, the wooden gauges supporting its ends. If the surface is intended to be smooth, a mixture of equal parts of silver-sand and slate dust, or of 2 parts silver-sand to 1 of dead plaster of Paris or powdered chalk, is sifted over the asphalte before it is perfectly set, and rubbed in with a flat heavy tool of wood. If the pavement is required to be rough, clean sharp grit is sifted thinly over it and beaten into the mastic with a heavy wooden block. When one portion of the pavement is complete, it is desirable to proceed to lay the next but one, leaving the intermediate space to be filled in afterwards when the first layer is quite cold and firm, so as to prevent its being injured. In laying these pavements the parts most exposed to wear are somewhat increased in thickness. In laying them upon suspension bridges or other flexible surfaces, the concrete is spread on a planked flooring, the joints of which are covered with battens nailed at one edge

only to allow the necessary play: a sheet of thin canvass is then spread evenly over the concrete and secured with nails, and upon this the mastic is spread. By mixing differently coloured sands with the mastic, and disposing it in patterns, imitations of mosaic work may be formed.

In the application of asphaltum with a view to exclude damp, as in the floors of cellars and basements, a brick invert laid in asphalte as a cement should be used, as at D, Fig. 74. Asphalted bricks and tiles for such purposes are prepared by heating them, and placing them in rows upon a flat surface between gauges rising to a sufficient height to allow a layer of the mastic a quarter of an inch thick to be spread over them: before the mastic is quite set, the bricks are separated from each other by passing a knife between them. In Fig. 74, the arrangement is shown for excluding water from a cellar. A is a

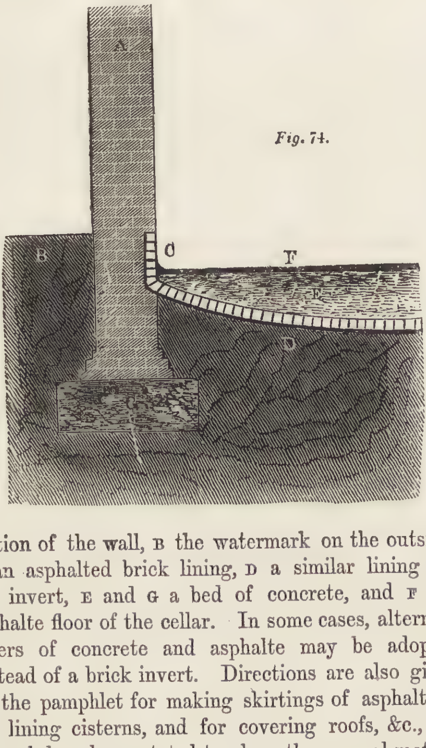


Fig. 74.

section of the wall, B the watermark on the outside, C an asphalted brick lining, D a similar lining for the invert, E and G a bed of concrete, and F the asphalte floor of the cellar. In some cases, alternate layers of concrete and asphalte may be adopted instead of a brick invert. Directions are also given in the pamphlet for making skirtings of asphaltum, for lining cisterns, and for covering roofs, &c., but enough has been stated to show the general method of applying this material. The thickness of asphaltum used for pavements, varies from half an inch to an inch and a quarter, the former being sufficient for common floors and court-yards, and the latter for carriage pavements. A thickness of from half an inch to five-eighths is sufficient for roofs and the coverings of arches for preventing the passage of water, and for the lining of tanks and ponds; and about a quarter of an inch is sufficient for the ground line of brickwork to prevent damp from rising.

An asphaltum surface admits of easy repair. By placing some hot mastic upon the place requiring it, the part may be cut away without injuring the adjacent work. The mastic thus removed may be remelted, and the edges of the old work being cut square, the hot material will readily adhere to them if free from dust and moisture.

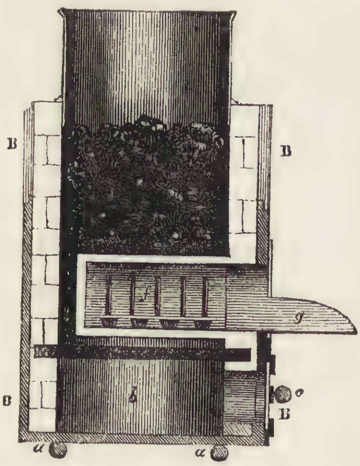
ASSAYING is a branch of chemical analysis, the object of which is, to determine the quantity of gold or silver in any mixture with the baser metals. It thus differs from chemical analysis, which takes account of *all* the ingredients of the body under examination. As gold and silver have for many ages afforded the most obvious standard of value in civilized countries, and considering what vast quantities of coin, plate, trinkets, and plate ornaments are being constantly produced, it was of great importance to persons who deal in such articles, to be able to decide quickly, and with certainty, on the exact portion of alloy which each piece might contain, and its exact weight to the minutest subdivision of weights. At an early period, in this country the trade of the goldsmith not only comprised as now the dealers in or makers of gold and silver articles, but also that trade which has, since the separation of the two ancient branches, received the name of Bankers. No tax was then, as now, levied on manufactured plate, but all articles made of gold and silver were to be of the same degree of purity as the coin of the realm. "Whatever was manufactured in London or in some of the larger places, was ordered to be assayed and stamped by the warders of the craft in such town; but whatever was made in places 'where no touch was ordained,' was to be stamped by the maker, and if found beneath the proper standard, it was confiscated to the crown.[1] In this state of affairs, any article of plate would be of the same value, in equal weights, as gold or silver in ingots; and hence, as occasion might require, the vessels being worth no more than their weight, would be on every pressing emergency readily converted into coin. The workmanship of plate would in that age cost but little, as luxury had not reached the point in that kind of art, which it soon afterwards attained in the hands of Benvenuto Cellini at Florence, and of his successors in the other parts of Europe. The taste displayed in the forms and decorations of gold and silver utensils was very coarse, both in France and in England. Voltaire, in his General History, says, that the work of the goldsmiths in Paris was so bad that the King, (Louis XII.) in 1501, forbade the manufacture, so that the French had their plate from Italy. There seems good reason to believe, that the English of that period did not excel the French artisans in the fabrication of gold and silver articles. We may thus account for what we find often stated in the records of that age, that the religious houses, the nobility, and rich individuals, gave up to the monarch, on pressing emergencies, their plate for the public service. Such a surrender in the present day, when a heavy tax and the workmanship of artists make plate of silver of more than double its value in weight, would be deemed a most oppressive requisition, whereas at the period referred to, the difference between making

(1) Bills of Parliament, 2d Henry VII. cap. 12 and 13.

payments in coined money or in manufactured gold and silver, would amount but to a trifle." [1]

Although the assay of the precious metals is very simple in principle, great skill is required in assaying. A skilful assayer is able from the sample of a few grains to determine the standard of very large masses of the most valuable metals. The principle of assaying is as follows:—when gold, silver, and platinum are exposed to the air, either in the solid state or in a state of fusion, they do not oxidize like the other metals, but retain their metallic lustre, on which account they obtained their name of *perfect* or *noble* metals. Hence, when a noble metal is alloyed with an inferior metal, if the alloy be melted in contact with the air, the latter will gradually become oxidized, and the scales of oxide rising to the surface can be removed from time to time, until the whole of the baser metal is separated. When the baser metal does not oxidize very readily, as is the case with copper, this separation becomes more difficult, and even impossible by heat alone if the proportion of copper be small; but by adding to the mixture a portion of some metal which oxidizes very readily, such as lead or bismuth, the more refractory metal oxidizes with greater ease, and thus the noble metal is left pure. On this account, litharge or oxide of lead was termed by the old chemists *the bath* of the noble metals, scouring or cleansing them, as it were, from their alloys of base metal, and leaving them bright and pure. In the refining of gold and silver, this process is often conducted on a large scale; but in assaying, where small samples only are operated on, the process of *cupellation* is adopted.

Fig. 75.



Cupellation is carried on in a small furnace capable of being raised to a heat sufficient to melt gold. In Fig. 75, BB, is a section of an assay furnace, which is capable of being moved forwards or backwards on two iron rollers *aa*; *b* is the ash pit with the grate above it, *c* is one of the ash pit dampers for regulating the draught, *g* is a mouth-plate for holding pieces of ignited charcoal. In the middle of this furnace is placed an earthen vessel *f*, called a *muffle*, of an oven form, vaulted at top with a level floor at bottom; it rests upon a plate which is covered with loam nearly an inch thick: it is open at one end and closed everywhere else except a few narrow slits through the top and sides. It is shown separately in Fig. 76, with the *muffle plate* Fig. 77, of the same size as the bottom of the muffle; the open end comes in contact with a door at the side of the furnace, and is generally luted thereto, so as to separate it entirely from the burning fuel. The body of the muffle is surrounded with coals, and before cupellation, is gradually heated to a glowing redness. Its use is to protect the small crucibles or cupels, ranged on its floor, from any impurities from the fuel, and at the same time to afford the melted metal a free access of heated air to promote the oxidation. The *cupels*, shown in section within the muffle, Fig. 75, are cubical or circular in form, with a shallow depression at the top to contain the metal, and small in proportion to the size of the muffle, so that a number of them may be at work at the same time. They are made of such substances as are not acted on by the fused oxides, and their texture is sufficiently loose to allow these oxides to penetrate them readily, and yet admit of being handled. Many substances fulfil these conditions, but the ash of burnt bone is generally used. The ash is powdered and sifted, and then repeatedly washed with water, to remove all saline and soluble matters: when dried, it consists of phosphate of lime with a little carbonate. This substance made into a paste with water or beer, is pressed into a mould to the proper shape: it is then taken out and dried at a gentle heat, and is lastly ignited to expel all moisture.

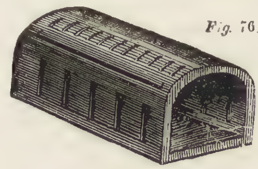


Fig. 76.

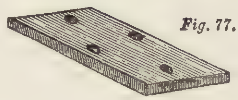


Fig. 77.

Before the cupels are put into the muffle, a little powdered chalk or sand is sprinkled on the floor of the muffle, to prevent the adhesion of the cupels by the litharge soaking through them. As the cupels cannot absorb more than their own weight of litharge, the quantity of fine metal to be assayed should not require more lead than the weight of the cupel.

For the assay of silver a clean piece of the metal is taken, not more than 36 grains, and less if the alloy appear to be considerable. It is flattened and weighed in a very sensible balance. It is then wrapped up in the requisite quantity of pure lead rolled out into a sheet; or the silver and the lead are folded together in a piece of paper. The muffle and the cupel being at a full red heat, the silver and the lead are put into the cupel with a pair of pincers, when they immediately melt. Aikin gives a beautiful and accurate description of the phenomena:—"The melted metal begins to send off dense fumes, and a minute stream of red fused matter is seen perpetually flowing from the top of the globule down its sides to

(1) Jacob on the "Precious Metals:" London. 1831.

the surface of the cupel, through which it sinks and is lost to view. This fume and the stream of melted matter consist of the lead oxidized by the heat and air, in one case volatilized, in the other vitrified, and in sinking through the cupel it carries down with it the copper or other alloy of the silver. In proportion to the violence of the heat is the density of the fume, the violence with which it is given off, the convexity of the surface of the globule of melted metal, and the rapidity with which the vitrified oxide *circulates*, (as it is termed,) or falls down the sides of the metal. As the cupellation advances, the melted button becomes rounder, its surface becomes streaky with large bright points of the fused oxide, which move with increased rapidity, till at last the globule, being now freed from all the lead and other alloy, suddenly *lightens*;[1] the last portions of litharge on the surface disappear with great rapidity, showing the melted metal bright with iridescent colours, which directly after becomes opaque, and suddenly appears brilliant, clean, and white, as if a curtain had been withdrawn from it. The operation being now finished, and the silver left pure, the cupel is allowed to cool gradually, till the globule of silver is fixed, after which it is taken out of the cupel while still hot, and when cold accurately weighed. The difference between the globule and the silver at first put in, shows the quantity of alloy, the globule being now perfectly pure silver, if the operation has been well performed."[2] Aikin states, that at the Mint two assays are always made of the same mass of metal, and no sensible difference, as ascertained by scales which turn with $\frac{1}{1200}$th of a grain troy, between the weight of the two buttons is allowed to pass. If they differ, the assay is repeated. The process is well performed, if the button of silver adheres but slightly to the cupel; if the shape is globular above and below, and not flattened at the margin; if the button be quite clean and brilliant, showing the beautiful white of pure silver, and not in any degree fouled or spotted with any remaining litharge: the surface of the metal must be disposed in scales or laminæ, the effect of sudden crystallization, which gives it a play of light and a striated lustre, very different from that of a perfectly even surface of a white metal, however pure. Examined by a microscope, this striated surface is still more striking; but when any alloy remains in the silver, the surface, although brilliant, appears smooth as if varnished.

In ordinary assays of gold or silver, copper is the alloy usually met with. If the metal be nearly pure, the cupel round the bottom is only stained yellow by the litharge. If copper be present, it leaves a brown grey stain. The other metals except bismuth scarcely penetrate the substance of the cupel, but remain on the edges of its cavity in the form of coloured scoriæ, of which iron is black, tin grey, and zinc a dull yellow.

(1) When the whole of the lead separates, the button seems agitated by a rapid movement, by which it is made to turn on its axis. Globules of iron and some other metals under the action of a strong heat behave in a similar manner.

(2) Aikin: ' Chemical Dictionary," our chief authority in this article

The time required for one assay, from putting the metal into the hot cupel to the *lightening* or purity of the button, is generally from 15 to 20 minutes, but the time is not of much consequence, as the button is equally pure after a rapid as after a slow cupellation. If the heat be too great, there is danger of error from the volatilization of the silver, but it is desirable to admit as much air into the muffle as possible consistent with a due regard to temperature. It is important also to attend to the gradual cooling of the button, because pure silver in a molten state absorbs oxygen from the air, and in returning to the solid state the whole is again expelled, so that if the cooling be rapid, the silver is spirted out in arborescent shoots, and some minute portions are thus thrown out of the cupel, and the assay is spoilt.

The proportion of lead to the silver to be assayed is also a point of importance. If too little lead be used, the button is very flat, rough at the edges, of a dull colour, with blackish spots, strongly adherent to the cupel, and foul with scoriæ on and about the button. If an excess of lead be employed, a small portion of the silver will be carried down into the cupel, and thus the sample of silver will be reported a little less pure than it really is. The quantity of lead required for each case of cupellation was formerly estimated by the use of *touch-needles*, or small slips or bars of metal made with pure silver, alloyed with known proportions of copper in a regularly increasing series, from the least to the greatest proportion ever required. The silver to be assayed was then compared with the touch-needles, in colour, tenacity, and other physical characters, and its alloy was estimated by that of the needle which it most resembled. These needles are seldom used now, as an experienced assayer is able to judge of the alloy by the ease or difficulty with which it is cut, the colour and grain of a fresh cut surface, the malleability, the change of surface when red-hot, and the general appearance.

The *assay of gold* is somewhat more complicated than that of silver. If silver be mixed with gold, although the latter be in very small proportion, it becomes a *gold assay*. Copper or any other base metal mixed with gold may be separated from it by cupellation, but the affinity of copper for gold is so strong as scarcely to be overcome by this method, unless a certain quantity of silver be added. Consequently, a subsequent operation is required to separate the gold from the silver as mixed in the button after cupellation. Gold is frequently alloyed with silver in some foreign coins, and in some kinds of manufacture. The separation of gold from silver is called *parting*, and is performed with dilute nitric acid, which dissolves the silver and leaves the gold untouched. If, however, the gold be in considerable proportion, it protects the silver from the action of the acid, and the parting is imperfect. In such case it is necessary to add silver, so as to give it a great excess over gold. About 3 parts silver to 1 part gold is the general proportion, and hence the process of parting is also called *quartation*, the relative proportion of gold being reduced to only one quarter of

the mass, but any greater proportion of silver may be parted with equal certainty. As the entire quantity of materials for the assay amounts to only a few grains, and as the intimate mixture of the silver is of great importance, it is usual to cupel them together with lead, so that they may be thoroughly combined into one small neat globule. The process is similar to the cupellation of silver, only a greater heat is required, which may be safely employed, as none of the mixture of gold and silver is lost by volatilization as pure silver is. The copper is worked off along with the litharge, but any minute portion of lead is got rid of by a second fusing. The cold button is then flattened with a hammer, again heated red-hot, and slowly cooled to anneal it and increase its malleability. It is then extended into a small plate, by being passed between rollers of polished steel, and is next rolled up in a loose coil called a *cornet*. This is put in a glass mattrass called a *parting glass*, and about twice or thrice its weight of pure dilute nitric acid is poured over it. The whole is slightly warmed, when a portion of the acid begins to decompose, and gives off red fumes of nitrous acid, and in about 15 or 20 minutes the whole of the silver is washed out, leaving the gold still coiled up in a slender brittle mass. The hot acid solution of silver is carefully poured off, and fresh acid, rather stronger, is added and heated for a few minutes, to clear away the remains of the silver. This is decanted off and added to the former solution. The parting glass is then filled with hot distilled water, and as it is of importance, for the sake of accuracy, to get out the cornet without breaking it into fragments, some of which might be lost, this is managed by inverting a small crucible over the top of the parting glass while full of water, suddenly inverting it, when the cornet falls gently down through the water into the crucible. The water is then let off; the crucible is dried and heated to redness in a muffle, when the cornet, which as it left the mattrass was a brown, spongy, brittle mass, shrinks in every direction, becomes firm, regains its metallic lustre, and when fully red-hot has all the appearance of pure gold; it has a beautiful lustre, and is soft and flexible. The gold is accurately weighed, and the process is finished. This weight indicates the absolute quantity of metal in the assayed sample. The difference between the weight of the button after cupellation, (deducting the silver added,) and the first sample, is the weight of the copper or other base metal in the gold; and the difference between the gold cornet together with the silver added, and the button after cupellation, is the quantity of silver alloyed with the gold. The silver left in solution after parting is usually recovered by immersing in it, when collected in quantity, some bright copper plates, which dissolve, and precipitate the silver in its metallic form.

In the assaying of gold and silver a peculiar set of assay weights is used. The actual quantity taken for an assay, is from 18 to 36 Troy grains for silver, and from 6 to 12 grains for gold. This is the integer, and whatever its real weight, it is called in England the *assay pound*. This imaginary pound is then subdivided into aliquot parts, which differ according to the metal. The silver assay pound is subdivided into 12 ounces, each ounce into 20 pennyweights, and these again into halves. Hence there are 480 *reports* for silver, this being the number of half pennyweights in the pound, and therefore each nominal half pennyweight weighs $\frac{1}{20}$th of a troy grain when the entire assay pound is 24 grains.

The report is made according to the proportion of fine metal. Thus the standard silver of the realm is reported by the assayers to be 11 oz. 2 dwt. *fine*, so that the remainder of the pound consists of 18 dwt. of alloy or copper, or 37 parts silver to 3 of copper. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains, and each grain into quarters. Hence there are only 384 separate reports for gold. The standard for gold coin is 22 carats fine, which gives 2 carats alloy. When the gold assay pound or integer is only 6 troy grains, the quarter assay grain only weighs $\frac{1}{64}$th of a troy grain.

Assayers also report gold and silver to be *better* or *worse* than the established standard. Thus gold of 20 carats is reported as *worse* 2 *carats*, being that proportion less than the standard of 22 carats. In a mixture of gold and silver, if the quantity of gold exceed that of the silver, it is called *gold parting*; if the contrary, *silver parting*. But in silver parting the report is first made on all the fine metal collectively as if for silver alone, so that if 10 oz. of fine metal be found, the assayer reports *worse* 1 *oz.* 2 *dwt.*; that is, 1 oz. 2 dwt. lower than the standard of silver, which is 11 oz. 2 dwt. fine.

When the assay pound is subdivided, as for silver, in the same manner as the troy pound, the lower denominations evidently bear the same relation to each other, which is useful in transferring the assay reports to real mixtures for use. But the carat subdivision for gold is confined to assaying, but its fractions being aliquot parts of the troy pound, the calculations for real use are easy. As the troy pound contains 5,760 grs., the carat corresponds to 240 grs. or 10 dwt., the assay grain or fourth of a carat to 60 grs. troy, and the assay quarter grain to 15 grs. troy. To this report the assayer having separated the gold, 4 oz. for example, adds 4 *oz. gold in a lb. troy*. But in gold parting he takes two equal assay pieces, treats one as a silver assay, and the other as a gold assay, to find the absolute quantity of each metal, after which the report is first made on the gold singly, to which is added the report of the silver separately. Thus if he find 4 oz. of gold, and 3 oz. of silver, he reports *worse* 14 *carats*, (2 carats being equivalent to an assay ounce, and consequently the 4 oz. of gold equal to 8 carats, which subtracted from 22 carats, the gold standard leaves 14,) to which report he adds *fine silver* 3 *oz.* But when the mixed metal contains more than half alloy, it is called *metal for gold and silver*, and the absolute quantity of each is reported separately.

The assay pound or integer is divided in a different manner in several parts of Europe. Aikin

explains the method adopted in France, Germany and China.

In France a small assay furnace has been invented by Messrs. Aufrye and D'Arcet, which with charcoal fuel can be raised to the proper degree of heat in half an hour.

Assaying now generally includes the determination of the quantity of some particular metal in an ore or mixture of the baser metals, such as the determination of the quantity of copper in the ore of that metal, with a view to ascertain the quantity which ought to be produced in smelting, and also, whether it would repay the smelter to work it. An assay may be conducted entirely by the *dry way*, or merely by heat with the assistance of fluxes; or by the *moist way*, in which acids or other re-agents are employed. In some cases both methods are used. The best and most elaborate treatise on the subject, is Berthier's *Traité des Essais par la Voie Sèche.* In two volumes, Paris, 1834. There is also a very good treatise in English, in one volume, partly founded on the above, entitled "Manual of Practical Assaying, intended for the use of Metallurgists, Captains of Mines, and Assayers in General," by Mr. John Mitchell. London, 1846.

ATMOSPHERE. [See Air, Anemometer, &c.]

ATMOSPHERIC RAILWAY. [See Railway.]

ATOM. ATOMIC THEORY. The word atom is derived from the Greek word ἄτομος, indivisible. Although matter is capable of being divided to an extent far beyond our powers of conception, yet it is very probable that there is a limit in nature, beyond which it is incapable of further subdivision. Supposing this limit to be attained, the minute particles of matter are then termed *atoms;* they are incapable of being further divided, and upon this property is founded one of the most beautiful doctrines of modern chemistry, a doctrine upon which the precision and consequent advance of this comprehensive science have mainly depended,—namely the Atomic Theory.

In every compound, whether formed artificially or by the hand of nature, the component parts always exist in the same relative quantities. Pure water, at all times and in all places, contains in every 100 parts 11.111 hydrogen, and 88.889 oxygen; marble always contains 56 parts of lime and 44 of carbonic acid, per cent.; common salt always contains 40 parts of sodium and 60 of chlorine, per cent. If, in forming these substances artificially, any one of the constituents be in excess, combination will still take place, but the excess will be rejected.

If, instead of considering the composition of the above-named substances by the per centage of their constituents, we take the smaller numbers that will represent their composition, then we say, that 1 atom of hydrogen weighing 1 + 1 atom of oxygen weighing 8 = 1 atom of water weighing 9. Or 1 atom of lime weighing 28 + 1 atom of carbonic acid weighing 22 = 1 atom of carbonate of lime weighing 50. Again, 1 atom of sodium weighing 24 + 1 atom of chlorine weighing 36 = 1 atom of chloride of sodium weighing 60. The meaning which is to be attached to the term *weight* in these examples, will be explained presently.

Now the atomic theory is based upon the proposition, that matter is capable of being reduced to atoms which do not admit of further division, and that the atoms of one kind of matter, which in the same substance have all the same size and weight, combine with the atoms of a different kind of matter, only in certain invariable ratios. It follows from this, that when two kinds of matter combine to form a compound, they combine atom to atom, for in order to combine chemically, the two bodies must be reduced to their state of greatest division, so that the respective atoms may be free to come within the range of each other's attraction. In such cases, an atom of one kind combines with an atom of the other kind. It cannot combine with half an atom, because no such thing exists, and it cannot combine with two atoms, because its attraction is satisfied with one. The two dissimilar atoms thus combined, now form a single compound atom, which in its turn is incapable of further division, for the very act of division is destruction, as far as the compound is concerned. Hence it will be seen, that, according to this theory, a simple atom is incapable of further division; a compound atom is capable of being divided into two simple atoms, but in such case, the compound ceases to exist. This obvious illustration explains, in a beautiful manner, the immutable nature of compound bodies, as they exist in nature or in art. If, for example, 1 grain weight of one kind of matter, consisting of 100 atoms, were combined with 1 grain weight of another kind of matter, also consisting of 100 atoms, the resulting compound would be homogeneous or of the same nature throughout; a substance would be formed possessing different properties from those of its constituents, and consisting of 100 compound atoms. If, however, to form the same substance, 1 grain or 100 atoms of the one kind of matter were presented to 2 grains or 200 atoms of the other kind of matter, the same compound would be formed, but the excess of 100 grains would be rejected, or be mechanically mixed with the compound.

Now if we suppose matter to be capable of infinite division, that atoms were in fact divisible, there is no sufficient reason why bodies should not combine in all proportions. The one hundredth of a grain in the above example, ought, in such case, to combine with the half hundredth, or the quarter hundredth, or any other proportional of a grain of the other substance, so as to form an infinite number of compounds, all possessing different properties to each other and to those of their constituents. That bodies do not combine in this indefinite manner, is a strong argument in favour of the atomic theory.

In the above remarks it has been supposed that dissimilar bodies combine only atom to atom. The real fact is, that an atom of one kind of matter may combine not only with 1 atom of another kind of matter, but with 2 atoms, with 3 atoms, or more, producing in each case compounds with distinct properties. Combinations of this kind have been

explained on one of two suppositions. 1. Suppose an atom of A to combine with an atom of B, to form a certain compound; in such case, the affinity of A for B may be so far unsatisfied, that an attraction may exist for another atom of B. Should the conditions be favourable for this combination, a second atom will combine with A, producing a compound with new properties; a third atom of B may also combine with A, forming a third distinct compound. 2. Instead of supposing the simple atom A to have a distinct attraction for 1, 2, or 3 atoms of B, we may suppose that the compound atom $A + B$ may exert an attraction for a second atom of B, and form a compound represented by $A + 2\,B$, and that this, in its turn, may attract a third atom of B, forming $A + 3\,B$, and so on.

For example, 32 parts of zinc combine with 8 parts of oxygen, to form 40 parts of oxide of zinc, and the affinity then seems to be satisfied: no further attraction seems to exist between these bodies; but if another portion of oxygen could be absorbed by the zinc, so as to form a second oxide, it would be another 8 parts, neither more nor less, and the deutoxide of zinc would consist of 32 zinc + 16 oxygen.

Again, 100 grains of mercury combine with 4 grains of oxygen, so as to form protoxide of mercury. As the combination is atom to atom, it has been supposed, in this, as in other similar cases, that there are as many atoms in 100 grains weight of mercury, as there are atoms in 4 grains weight of oxygen. But in this case, the affinity is not satisfied; an additional quantity of oxygen can be combined with the same quantity of mercury; an atom of mercury has an attraction for two atoms of oxygen, or 100 grains of mercury will combine with 8 grains of oxygen, and the second oxide contains twice as much oxygen as the first. If a third oxide were to be formed with 100 grains of mercury, it would contain not 9, nor 10, nor 11, but exactly 12 grains of oxygen. Thus molybdenum combines with oxygen in this way, forming three distinct oxides: the first oxide consists of 1 atom of the metal + 1 atom of oxygen; the second oxide contains one atom of the metal + 2 atoms of oxygen; and the third consists of 1 atom of the metal + 3 atoms of oxygen.

In these, and all such examples, it is of no consequence which of the combining substances be taken as the constant quantity; 100 of A may unite with 50 of B, or with twice as much, namely 100, or with thrice as much, namely 150; or, what is the same thing, 100 of B, may unite with 200 of A, or with half as much, or one third as much, for it will be observed, that the multiple ratio affects one kind of matter as much as it affects the other.

Gaseous bodies, which have a chemical action on each other, also unite in the same definite manner. For example, the proportions of oxygen that combine with any quantity of nitrogen to form compounds, will be to each other as the numbers 1, 2, 3, 4, 5, and never to any intermediate numbers. But instead of taking gases by weight, we may take them by bulk or volume, and they will be found to combine in the most simple ratios, the ratio being as 1 to 1, 1 to 2, or 1 to 3. Thus 1 volume of oxygen requires exactly 1 volume of hydrogen to form the deutoxide, and 2 volumes to form water. 1 volume of hydrogen requires 3 volumes of nitrogen, to form ammoniacal gas, and so on.

Hence the law of combination may be thus concisely expressed:—When a body A combines with a body B in several proportions, the numbers expressing these proportions are integer multiples of the smallest quantity of B that A can absorb. The law may be also thus expressed:—When two bodies combine in several proportions, the first proportion is either a multiple or a submultiple of all the rest.

These laws of definite proportions, and of the atomic theory in reference to weights and volumes, are well illustrated by the compounds of nitrogen and oxygen: these bodies unite with each other in 5 proportions, and in the simplest ratios, forming two oxides and three acids.

	Atoms or equivalents of Nitrogen and Oxygen.	Weights of the atoms or equivalents of Nitrogen and Oxygen.	Atomic weight of the compound.	Volumes of Nitrogen and Oxygen.	Resulting volume of the compound.
	N. O.	N. O.		N. O.	
1 atom of the Protoxide of Nitrogen consists of..	1 + 1	14 + 8	22	1 + 0.5	1
1 atom of the Deutoxide of Nitrogen	1 + 2	14 + 16	30	1 + 1	2
1 atom of the Hyponitrous Acid..	1 + 3	14 + 24	38	1 + 1.5	
1 atom of the Nitrous Acid	1 + 4	14 + 32	46	1 + 2	1
1 atom of the Nitric Acid	1 + 5	14 + 40	54	1 + 2.5	

In the above examples the oxygen combines in regular arithmetical progression. This, however, is not always the case. The law of multiple ratios simply requires, that the proportionals shall all be multiples of the smallest. Thus, in the known compounds of chlorine and oxygen, the oxygen combines by weight or volume, with a weight or volume of chlorine, according to the numbers 1, 3, 4, 5, 7. Should any intermediate compounds be discovered, the oxygen will be in the proportion of 2 and 6; such compounds may, however, be impossible.

It is necessary to attach a precise meaning to the term *weight*, or *combining weights*, when speaking of the union of chemical elements. Thus we say, that water is composed of 8 parts by weight of oxygen, and 1 part by weight of hydrogen. In such case, 8 is called the *equivalent* or *combining weight* of oxygen, and 1, the equivalent or combining weight of hydrogen, and $8 + 1 = 9$, is the equivalent or combining weight of water. But we may also represent hydrogen by 100, or by 1000, or any other number, provided all the numbers be multiplied in an equal ratio; or hydrogen may be represented by $\frac{1}{100}$, or $\frac{1}{1000}$, if all the other numbers be equally reduced. If hydrogen were represented by 100, oxygen would

be 800, and nitric acid 5,400. Or if hydrogen were 0.01, oxygen would be 0.08. It is the ratio that gives value to these numbers. When we say that 40 parts sulphuric acid saturate 48 parts potash, there is nothing in these numbers of any particular value; for 20 and 24, 5 and 6, would do as well, these numbers being in the same ratio as 40 and 48, and this is the ratio between the sulphuric acid and the potassa; but as small numbers are more easily remembered than large ones, it is an object to reduce the equivalent numbers to the lowest ratio that can be obtained.

Berzelius assumes oxygen as = 100, other chemists have taken oxygen as = 1, in which case the whole scale of equivalent numbers must be reduced to one eighth of what they would be when hydrogen is = 1. Thus sulphuric acid, which in the hydrogen scale = 40, would in the oxygen scale = 5; nitric acid, instead of being 54, would be 6.75; lime, instead of being 28, would be 3.5; carbonic acid, instead of 22, would be 2.75; and hydrogen would be 0.125. Nearly one half of the ascertained numbers would be fractional. Dr. Thomson gives the following reasons for preferring the oxygen scale: "Hydrogen, so far as we know at present, combines with but few of the other simple bodies; while oxygen unites with them all, and often in various proportions. Consequently, very little advantage is gained by representing the atom of hydrogen by unity; but a very great one by representing the atom of oxygen by unity; for it reduces the number of arithmetical operations respecting these bodies, to the addition of unity; and we see at once, by a glance of the eye, the number of atoms of oxygen which enter into combination with the various bodies."

In the *tables of equivalents*, as they are called, which have been constructed with great care by first-rate chemists, the quantity, but not the quality, of the weights is given. It is not stated whether these weights are grains, or ounces, or pounds. In the laboratory, or in the chemical manufactory, it may be any one of them, or it may be hundred-weights or tons. In theory, however, a very different denomination is implied. When it is stated, that potash consists of 40 potassium + 8 oxygen, these numbers are referred to the unit by which all elementary bodies are measured; this unit is hydrogen, and its equivalent number, or combining weight, is 1.

Dr. Dalton was the first who conceived clearly the idea, that from the relative actual weights of the elements in the mass of any compound body, the relative weights of the ultimate atoms of bodies might be inferred. Water, he conceived, consisted of 1 part by weight of hydrogen, and 8 parts by weight of oxygen, and he supposed that when two combinations of two bodies could be obtained, that the first must be composed of an atom of each, and the second, of 2 atoms of the one, and 1 atom of the other. Applying this reasoning to the compound of oxygen and hydrogen, he supposed that 1 atom of hydrogen + 1 atom of oxygen formed water, and hence that the weights of the atoms must be in the same ratio as the weights of the total quantities that compose water. In this way he examined a large number of compounds, assuming the weight of hydrogen as unity, and from that determining the weight of the atoms of other elements by representing them as so many times heavier than the atom of hydrogen, the number of times being discovered by comparing the weights of different elements. These weights were determined by the analysis of the compounds formed either with one part hydrogen, or with a given weight of some other element whose relative atomic weight to that of hydrogen had been ascertained. In this way the weights of the atoms of other bodies were expressed in atoms of hydrogen, each of which was denoted by unity.

The atomic weight of one body being thus arbitrarily fixed, the atomic weights of other bodies were found in the following manner. 100 parts of water contain, according to analysis, 11.111 hydrogen and 88.889 oxygen. Assuming that in the composition of water every atom of hydrogen is combined with 1 atom of oxygen, then the weight of 1 atom of hydrogen = 11.111 : 88.889 = 1 : 8 and this last number is the atomic weight of oxygen.

100 parts of sulphuretted hydrogen contain 5.9 parts of hydrogen and 94.1 parts of sulphur. Assuming that this compound contains equal numbers of atoms of hydrogen and sulphur, we have the proportion 5.9 : 94.1 = 1 : 16; or the atomic weight of sulphur is 16, if that of hydrogen be assumed as = 1.

On examining the relation of sulphur to oxygen, we find that 100 parts of sulphurous acid contain 50 of sulphur and 50 of oxygen; and 100 parts of sulphuric acid 40 sulphur and 60 oxygen. Now 50 : 50 = 16 : 16, and 40 : 60 = 16 : 24; and since the atomic weight of sulphur is 16, that of oxygen 8, we may conclude, that in sulphurous acid, 1 atom sulphur = 16, is combined with 2 atoms oxygen = 16, and in sulphuric acid with 3 atoms oxygen = 24.

Carbonic oxide contains 6 parts carbon combined with 8 oxygen; and carbonic acid 6 carbon with 16 oxygen. The atom of carbon is estimated at 6, supposing that in carbonic oxide it is combined with 1, and in carbonic acid with 2 atoms of oxygen.

Sulphuret of carbon contains 6 parts carbon united with 32 sulphur; therefore, 1 atom of carbon with 2 atoms of sulphur.

In ammonia 14 parts of nitrogen are combined with 3 of hydrogen; therefore, 1 atom of nitrogen with 3 atoms of hydrogen.

In the yellow oxide of lead, 103.8 lead are combined with oxygen; the atomic weight of lead may therefore be estimated at 103.8. Galena is a compound of lead and sulphur, in the proportion of 103.8 : 16, and this compound must be regarded as containing equal numbers of atoms of its elements.

In this way the atomic weight of hydrogen being assumed = 1, the following atomic weights have been determined; oxygen 8, sulphur 16, carbon 6, nitrogen 14, lead 103.8. In a similar manner the atomic weights of other elements have been calculated, as set forth in the following table:—

LIST OF ELEMENTARY BODIES, WITH THEIR ATOMIC WEIGHTS AND SYMBOLS.

	Symbols.	Elementary Bodies.	Atomic Weights.
	H.	Hydrogen	1
	O.	Oxygen	8
	C.	Carbon	6
	B.	Boron	11
	P.	Phosphorus	32
	S.	Sulphur	16
	Se.	Selenium	40
	I.	Iodine	126
	Br.	Bromine	78
	Cl.	Chlorine	36
	F.	Fluorine	19
	N.	Nitrogen	14
(Kalium)	K.	Potassium	40
(Natrium)	Na.	Sodium	24
	Li.	Lithium	7
	Ba.	Barium	69
	Sr.	Strontium	44
	Ca.	Calcium	20
	Mg.	Magnesium	12
	La.	Lanthanum	44
	Ce.	Cerium	46
		Didymium.	
	Y.	Yttrium	32
		Erbium.	
		Terbium.	
	G.	Glucinum	5
	Al.	Aluminum	14
	Th.	Thorium	60
	Zr.	Zirconium	23
	Si.	Silicium	15
	Ti.	Titanium	24

	Symbols.	Elementary Bodies.	Atomic Weights.
	Ta.	Tantalium	185
		Niobium.	
		Pelopium	
(Wolfram)	W.	Tungsten	101
	Mo.	Molybdenum	48
	V.	Vanadium	68
	Cr.	Chromium	28
	U.	Uranium	60
	Mn.	Manganese	28
	As.	Arsenic	75
(Stibium)	Sb.	Antimony	129
	Te.	Tellurium	64
	Bi.	Bismuth	213
	Zn.	Zinc	32
	Cd.	Cadmium	56
(Stannum)	Sn.	Tin	59
(Plumbum)	Pb.	Lead	104
(Ferrum)	Fe.	Iron	28
	Co.	Cobalt	30
	Ni.	Nickel	28
(Cuprum)	Cu.	Copper	32
(Hydrargyrum)	Hg.	Mercury	100
(Argentum)	Ag.	Silver	108
(Aurum)	Au.	Gold	200
	Pt.	Platinum	99
	Pd.	Palladium	54
	R.	Rhodium	52
	Ir.	Iridium	99
	Os.	Osmium	100
		Ruthenium.	

In this table the elementary substances whose names are printed in Italics, have not yet been examined with sufficient care to determine their atomic weights.

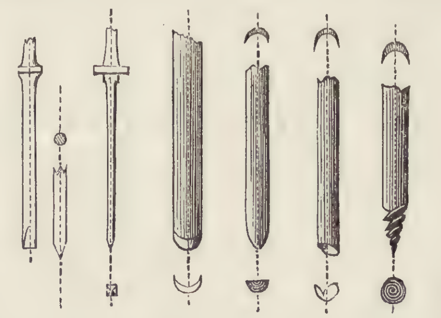
In the preceding details the combining ratio is stated as always consisting of 1, 2, 3, 4, &c. to 1. In some works on Chemistry we find ratios which appear to contradict this law. Thus the sesquioxide of iron is said to consist of 1 atom of iron, with $1\frac{1}{2}$ atom of oxygen; but as half atoms involve a contradiction of terms, it is usual to get over the difficulty by doubling the numbers, so as to make 1 atom of sesquioxide of iron to consist of 2 atoms iron, and 3 of oxygen.

Another supposed difficulty in the way of the atomic theory has been in such combinations as sulphuric acid and water, alcohol and water, in which the existence of determinate ratios is indistinct, for these substances appear to combine in all proportions. Such too is the case with the alloys of metals. But it generally happens that where bodies appear to combine in all proportions the affinity is weak; the compound is really not a new substance possessing properties peculiar to itself, and which distinguish it from every other substance in nature; but the compound possesses most of the characters of a mixture; its properties form a mean between those of its constituents, in which the distinctive properties of each constituent can be recognised with greater or less distinctness.

After all, the doctrine of definite proportions may only be a mere expression of facts essentially different from the real atomic constitution of bodies. Nevertheless, it is a true theory, inasmuch as it generalizes the innumerable facts of chemistry, and inscribes them in a sort of short-hand, which is as remarkable for its simplicity as for the truth of its indications.

AUGER. AWL. These are instruments for boring wood, of which there are a great number of varieties. The *brad-awl* is the simplest. It consists of a cylindrical wire with a chisel edge, Fig. 78. It is sometimes sharpened with three facets as a triangular prism. The awl used by wire-workers, such as bird-cage makers, &c. Fig. 79, is square and sharp on all

Fig. 78. *Fig.* 79. *Fig.* 80. *Fig.* 81. *Fig.* 82. *Fig.* 83.



its edges, and tapers off very gradually until near the point, where the sides meet rather more abruptly. Tools of this kind displace rather than remove the material which they penetrate.

Most of the boring instruments used in carpentry are fluted, in order to give room for the shavings. The *shell-bit*, Fig. 80, also called the *gouge-bit* and *quill-bit*, is sharpened at one end like a gouge, and when revolving it shears the fibres of the wood round the margin of the hole, and removes the wood almost

as a solid core. Very small tools of this kind are used for boring holes in some kinds of brushes.

The *spoon-bit*, Fig. 81, is generally bent up at one end, so as to make a taper point. It acts something like a pointed drill, but has a keen edge suitable for wood. The *cooper's dowel-bit*, and the *table-bit* for making holes for the wooden joints of tables, are of this kind. When the end is bent into a semicircular form, it is called a *duck nose-bit* from its resemblance, and a *brush-bit* from the use to which it is applied.

The *nose-bit, slit-nose-bit,* and *auger-bit*, Fig. 82, is slit up a small distance near the centre, and the larger piece of the end is then bent up nearly at right angles to the shaft, so as to act like a paring chisel, and the corner of the reed near the nose also cuts slightly. On a large size this tool is called the *shell-auger*, and is sometimes made 3 inches in diameter and upwards, with long movable shanks for boring pump-barrels. Before using nose-bits a preparatory hole is made with a brad-awl or centre punch; with augers a preparatory hole is always made with a gouge or centre bit of the same size as the auger.

The *gimlet*, Fig. 83, is also a fluted tool, but it terminates in a sharp worm or screw, beginning as a point and extending to the full diameter of the tool, which is thus drawn by the screw into the wood. The gimlet acts like an auger, by cutting the wood by the angular corner between the worm and the shell. When the shell is full of wood the gimlet is withdrawn and emptied.

The *centre-bit*, Fig. 84, consists of three parts, viz. a centre point or *pin*, which serves as a guide; a thin shearing point or *nicker*, which cuts through the fibres like the point of a knife; and a broad chisel edge or *cutter*, placed obliquely, to pare up the wood within the circle marked out by the point. The cutter should have a little less radius, and less length than the nicker. There are many forms of centre-bits described in Mr. Holtzapffel's excellent work, which ought to be in the hands of every practical and amateur mechanic, whether in wood or metal.

Fig. 84.

Various forms of auger are made with spiral stems, so that the shavings may ascend the hollow worm, and thus save the trouble of withdrawing the bit so frequently. The *twisted gimlet*, Fig. 85, is a tool of this kind. It is made with a conical shaft, round which is filed a half-round groove, one edge of which is thus sharpened, and gradually enlarges the hole after the worm has penetrated, and being smaller than in the common gimlet, there is less risk of splitting. The common *screw auger*, Fig. 86, is forged as a parallel blade of steel, and twisted while red-hot. The end terminates in a worm, by which the auger is gradually drawn into the work. The same kind of shaft is sometimes made with a plain conical point, with two scoring cutters and two chisel edges, forming a sort of double centre-bit.

Fig. 85.

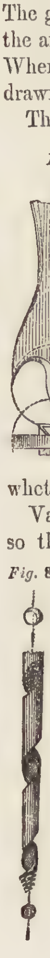
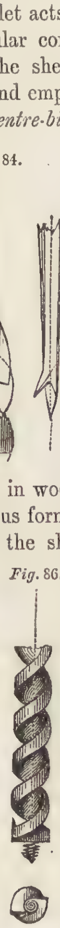


Fig. 86.



The various kinds of boring bits are usually set in motion by means of the carpenter's brace, one end of which receives the bit, and the other end, consisting of a swivelled head or shield, is pressed forward horizontally by the chest of the workman. Augers are usually moved by transverse handles. Some augers are made with shanks, and are riveted into the handles like the common gimlet; the most common method is to form the end of the shaft into a ring or eye, through which the transverse handle is tightly drawn. Brad-awls and similar tools requiring only a slight force have straight handles.[1]

Mr. Richardson[2] states on the authority of Junius, that the word awl has the same origin with *eel*, and was so called because it can introduce and insinuate itself like an eel.

AUTOMATON, from αὐτὸς and μάομαι, a *self-moving* machine, or one so constructed, that by means of internal springs and weights or other well known contrivances, it may move for a considerable time as if endowed with life. According to this definition, clocks and watches are automata; indeed, the term *automatic machinery* has of late years been applied to the self-acting looms and other machines which are now so extensively used in the manufactures of this country.

Many early writers delight in narratives of wonderful toy automata, but as they have not stated the mechanical contrivances by which the results were brought about, it is of no use to repeat them here. As an example of the small degree of reliance which can be placed on these narrations, we may refer to the wooden eagle of John Müller of Nuremberg, commonly called Regiomontanus, which flew forth from the city of Nuremberg aloft in the air, and met the emperor Maximilian as he was approaching the city; having saluted him, the bird returned with him to the city gates. This story is gravely related by such eminent authorities as Kircher, Porta, Gassendi, Lana, and Bishop Wilkins, but unfortunately for the truth of it, they do not agree in their dates. Some say it was in the time of Maximilian, others in the time of his grandson Charles V., who was born 64 years after the death of Müller. The same philosopher is also said to have made an iron fly, which at a feast, flew forth from his hand, and taking a round, returned thither, to the astonishment of the guests. This, if true, was probably some kind of magnetic trick.

In approaching more modern times, our information is more precise, and the automata are less marvellous. The best examples are those by Vaucansen, Camus, Kempelen and others, and are described by Sir David Brewster in his entertaining little work on Natural Magic. The Automaton

(1) Holtzapffel: "Turning and Mechanical Manipulation," vol. ii.

(2) A New Dictionary of the English Language, by Charles Richardson. London, 1839.

Chess-player of Kempelen was a clever hoax, and the inventor himself was really ashamed at its success. A full history and description of this machine, if such it may be called, is given by the editor in his "Amusement in Chess," London 1845. A few years ago, the editor saw in a watch-maker's room at Geneva, a small automaton, which he believes was invented by M. Maillardet, a clever mechanical artist of the last century. It consisted of a small nest about 3 inches in diameter. On touching a spring, a bird of beautiful plumage, not larger than a small humming-bird, started up and perched on the edge of the nest, fluttering its wings and opening its bill with the tremulous vibration peculiar to singing birds. It then began to warble a rapid succession of notes similar to the song of the nightingale, and loud enough to be heard over the whole room. It then suddenly darted down into its nest, and the nest closed upon it. The song continued about four minutes, and the exhibitor stated that the bird warbled several different strains. We learn from Dr. Brewster,[1] that the great variety of notes was not produced by a corresponding number of pipes, for which there was evidently no room, but the artist ingeniously managed to have only one pipe, the vacuity of which is shortened or lengthened by a piston working inside, and thus producing sounds graver or more acute according as the machinery operates upon it.

The automaton which has, perhaps, received most attention is the speaking machine. A speaking automaton was constructed by Kempelen, and has received further improvements from professors Willis and Wheatstone. A machine of this kind, constructed by a German, was exhibited a few years ago at the Egyptian Hall in London. We cannot say that it was successful.

AXIS, a word used in various senses in different departments of science, in which case it is connected with other terms which give it a special meaning and application. Thus we speak of the *axis of inertia, of rotation, of refraction, of polarisation,* &c. When used by itself, the term generally refers to the axis of rotation or of symmetry. Thus, when a body has a motion of rotation or revolution, the line round which it rotates or revolves is called the *axis.* So also a line, on both sides of which the parts of a body are similarly disposed, extending as far in one direction as in the other, and in exactly opposite directions, is called the *axis of symmetry.*

The mechanical properties of the axis of rotation are of great importance. In some cases, when the body revolves, the axis itself is movable and in actual motion, as in the earth, the planets, a common spinning top, &c., but generally in mechanics the axis is immovable, or may be regarded as such, as in wheel work, the moving parts of watches and clocks, turning-lathes, mill-work, hinges, &c. Where the axis, or pivot, or joint is not fixed, it may be considered so in reference to the mechanical effect, as in scissors, shears, pincers, &c.

[1] Edinburgh Encyclopædia, vol. iii. 1830.

In cases where wheel-work is concerned, the body generally turns continually in the same direction, each of its points describing a complete circle during every revolution of the body round its axis; but in some cases the motion is alternate or reciprocal, as in the pendulums of clocks, the balance-wheels of chronometers, the treadle of a lathe, doors or lids on hinges, scissors, pincers, &c. When the alternation is constant and regular, as in pendulums and balance-wheels, it is called *oscillation* or *vibration.*

When a solid body is movable on a fixed axis, it is susceptible of motion only by rotating on that axis. If it be subjected to the action of instantaneous forces, one or other of the following effects will be produced:—1. The axis may resist the forces and prevent any motion. 2. The axis may modify the effect of the forces, thereby sustaining a corresponding *percussion,* and the body receiving a motion of rotation. 3. The forces may cause the body to rotate round the axis even were it not fixed, in which case the axis will suffer no percussion.

If instead of instantaneous forces, the body be subject to continuous ones, similar effects will be produced, only instead of percussion we get pressure. But "the impressed forces are not the only causes which affect the axis of a body during the phenomenon of rotation. This species of motion calls into action other forces depending on the inertia of the mass, which produce effects upon the axis, and which play a prominent part in the theory of rotation. While the body revolves on its axis, the component particles of its mass move in circles, the centres of which are placed in the axis. The radius of the circle in which each particle moves, is the line drawn from that particle perpendicular to the axis. A particle of matter having a circular motion is attended with a centrifugal force proportionate to the radius of the circle in which it moves and to the square of its angular velocity. When a solid body revolves on its axis, all its parts are whirled round together, each performing a complete revolution in the same time. The angular velocity is consequently the same for all, and the difference of the centrifugal forces of different particles must entirely depend upon their distances from the axis. The tendency of each particle to fly from the axis arising from the centrifugal force is resisted by the cohesion of the parts of the mass, and in general, this tendency is expended in exciting a pressure or strain upon the axis. This pressure or strain is, however, altogether different from that already mentioned, and produced by the forces which give motion to the body. The latter depends entirely upon the quantity and directions of the applied forces in relation to the axis; the former depends on the figure and density of the body and the velocity of its motion."

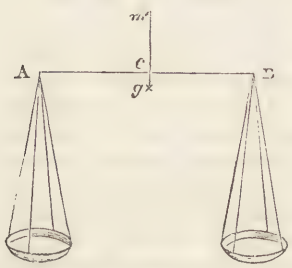
These very complex effects do not readily admit of popular exposition; but the reader who is interested in the subject, will find it treated in a lucid manner in the tenth chapter of Dr. Lardner's Mechanics, in the Cabinet Cyclopædia.

AXLE. [See Wheel Carriages.]

BAKING. The process of drying and consolidating a substance by means of heat. [See BREAD, BISCUIT, POTTERY, PORCELAIN, SUGAR, &c.]

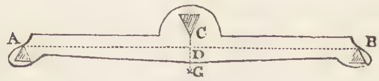
BALANCE. An instrument for ascertaining the weight of substances. It is of extensive use in the common affairs of life, in the arts, and in experimental science. It consists essentially of a lever of the first kind, in which the fulcrum is between the power and the weight to be raised. This lever, called the *beam*, A B, Fig. 87, has its fulcrum or axis of motion *c* in the centre, so that the two *arms*, A *c*, *c* B, are equal. The two extremities of the beam, called the *points of suspension*, support the scale-pans, one of which is for the weights and the other for the substance to be weighed: *g* is the centre of gravity of the beam, and is situated a little below the fulcrum, for if situated in that point, the beam, instead of always being horizontal when the arms are in equilibrium, would rest indifferently in any position; and if the centre of gravity were above the centre of motion, the least disturbance would cause the beam to upset. The points of suspension should be situated so that a straight line A B joining them is perpendicular to the line of symmetry formed by joining the centre of gravity *g* with the centre of motion *m*. The direction of the line *m g* is indicated by a slender pointed needle or tongue, rising perpendicularly above or below the beam: a graduated scale or arc behind it shows the deviation of the tongue from the perpendicular, and renders sensible the slightest motion of the beam. When the needle points to the zero line of the scale, which is also in the vertical of the centre of gravity, the beam must be horizontal. By means of this index we can also ascertain whether equilibrium has been attained, without waiting until the beam has ceased to oscillate; for, if it be really in equilibrium, the needle will describe equal arcs on the graduated scale on each side of the zero point, but, if there be not equilibrium, the needle will move through a larger number of degrees on one side of the zero point than on the other.

Fig. 87.



In a perfect balance, all the parts ought to be symmetrical with the centre of gravity; that is, the parts on either side of this point ought to be exactly equal in every respect. But such perfection cannot be attained in practice; the most skilful workman cannot make the two arms perfectly equal; but he approaches this state of perfection as closely as possible. In order to reduce the friction on the axis, the beam is made as light as is consistent with perfect inflexibility. To diminish the extent of surface in contact with the axis, the beam is supported on two sharp edges of tempered steel, C, Fig. 88, lying in the same straight line, and supported on two planes of steel or agate, finely polished, and placed with the greatest care in the same horizontal plane.

Fig. 88.



The scale-pans are also suspended on knife-edges A B: G is the centre of gravity of the whole beam. D is the point of coincidence of A B and C G.

Equality in the length of the arms can be tested in two or three ways. If the balance with its pans vibrate freely, and rest in a horizontal position, and after changing the pans from one end to another the balance again rests horizontally, the arms are almost sure to be equal. Or by changing the weights from one pan to another, if equilibrium be still retained, the lengths of the arms are equal.

The weights are usually of brass; but the smaller ones should be of platinum, which is not liable to oxidation or corrosion; and the weights made of this metal can be cleaned from dirt by a slight wiping, or by momentary exposure to the flame of a spirit-lamp. The minute weights, such as the fractions of a grain, are taken up by means of small brass pincers or forceps, as they are too small to be taken up quickly and safely by the hand. There is also danger of moisture or other extraneous matter being communicated to them by handling. The weights are furnished by the maker in sets, from 500 troy grains down to tenths and hundredths of a grain. These weights are frequently arranged in a geometrical series,—1, 2, 4, 8, 16, &c., grains—the advantage of which is that a smaller number of weights is required than in any other system; but the decimal division is convenient in practice. In this case the weights would be 1, 2, 3, 4, &c., up to 10 grains; 10, 20, 30, up to 100; 100, 200, 300, up to 1,000; 1,000, 2,000, up to 9,000. For the fractions the weights would be .1, .2, .3, &c.; .02, .03, .04, &c.; .001, .002, .003, &c. In this way the trouble of adding is avoided, for the number of weights in the scale is equal to the digits in the number by which the grains are expressed. Thus a load of 735.4 grains is counted by weights of 700 grains, 30 grains, 5 grains, and 4 tenths of a grain. In some of the modern forms of balance one arm is divided into 10 parts, and a small weight, formed of wire twisted into a fork, and weighing $\frac{1}{10}$th of a grain, placed upon one of the divisions of the arm, which thus acts as a steelyard, indicates from $\frac{1}{100}$th to $\frac{9}{1000}$th of a grain.

The accuracy of the subdivisions is tested by making up equal quantities from different weights, and comparing them together in the balance, a large weight previously compared with a standard weight of good authority being tried against 8 or 10 smaller, as the 100 grain weight against weights of 40, 30, 10, 8, 5, 4, 2, and 1; and then again from a quantity made up of several to remove some and replace them by others, as, for example, for the 30 grain weight to substitute a 10 and four 5 grain weights. The fractions of the grain should be examined in a similar manner,

In weighing for the purposes of chemical analysis, an error amounting to the thousandth of a grain might be of importance. But should the arms of the balance be unequal, a very exact result can still be obtained by the method of *double weighing* invented by Borda. To weigh a body is to ascertain how many times the weight of this body contains another weight of known value. Place the body, which we will call M, in one scale-pan, and produce equilibrium by placing in the other scale-pan some shot, or dry sand, or other substance in a state of minute division, so that very small portions may be added or subtracted, as occasion requires: by this means the needle can be brought exactly to zero, thereby indicating the horizontality of the beam. Then remove the body M, and substitute for it known weights until the beam is again horizontal. The amount of this weight will express exactly the weight of the body M, because these weights being placed under exactly the same circumstances of equilibrium as the body M produce exactly the same effect. In this way it is not only possible, but easy, to weigh truly with a false balance.

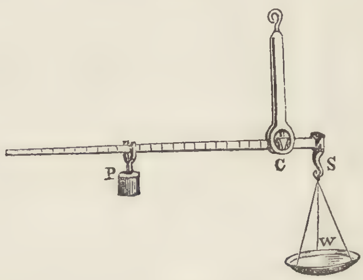
The tendency of a balance to return to and oscillate about the position of rest, after being disturbed, is called its *stability*, which is determined by the position of the centre of gravity below the point of support. Stability is far more easily attained than *sensibility*, or the tendency of a loaded balance, when poised, to turn when a very small additional weight is placed in either scale. In comparing the stability of one balance with that of another, a small amount of disturbance is given to both, such as one degree, and, if the force with which the first endeavours to recover its position be double or triple that of the second, the stability of the first is double or triple that of the second. The sensibility is ascertained by comparing the angles through which very small equal weights incline the balances. Thus, if a grain weight put into a scale-pan of each inclines one balance 4 degrees, and the other only 2 degrees, the first is twice as sensible as the second. The sensibility of a balance is also ascertained by observing the smallest additional weight that will turn it, and then comparing this addition with the whole load. Thus, if a balance have a troy pound in each scale-pan, and the horizontality of the beam varies by a small quantity, only just perceptible, on the addition of $\frac{1}{100}$th of a grain, the balance is said to be sensible to the $\frac{1}{1152000}$th part of its load, with a pound in each scale, or that it will determine the weight of a troy pound within $\frac{1}{576000}$th of the whole. One of the most sensible balances ever constructed was that employed for verifying the national standard bushel, the weight of which, together with the 80 pounds of water which it should contain, was about 250 lbs. With this weight in each scale, the addition of a single grain occasioned an immediate variation in the index of $\frac{1}{20}$th of an inch, the radius being 50 inches; so that this balance was sensible to $\frac{1}{1750000}$th part of the weight to be determined.

The sensibility of a balance is usually increased by increasing the length of its arms; by diminishing the weight of the beam; by diminishing the distance between the centres of gravity and motion; by diminishing the distance of the line joining the points of suspension from the centre of motion: the sensibility is also greater when the load is smaller.

Accurate weighing is a very difficult and delicate operation, requiring numerous precautions which the reader will find clearly stated, together with a large amount of information in the balance, weighing, &c. in the second section of Faraday's invaluable work on "Chemical Manipulation."

The ordinary weights and scales for common purposes do not require particular description, but there are various modifications of the lever of the first kind in common use, which are used as weighing machines. Such is the *Roman statera* or steelyard, Fig. 89, which consists of a beam of iron resting upon knife edges on a pivot, with one arm longer than the other. If the shorter arm with the scale be sufficiently heavy to balance the longer arm when the instrument is unloaded, the beam will, of course, be horizontal.

Fig. 89.



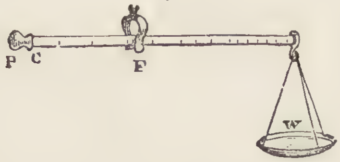
The substance to be weighed, W, is attached to a hook on the shorter arm, and a constant weight, P, is made to slide upon the longer arm, until equilibrium is established. Now, in the lever, the condition of equilibrium is that the weight W multiplied into its distance from the fulcrum, is equal to the power or counterpoise P multiplied into its distance from the fulcrum. Now as the distance of the weight from the fulcrum is constant, and the counterpoise is also constant, it is evident that in whatever proportion W is increased or diminished, the distance between P and the fulcrum must be increased or diminished in the same proportion.

In the ordinary steelyard, the centre of gravity is not at the fulcrum; so that when the weight P is removed, the longer arm usually preponderates; hence the graduation of the instrument must be commenced, not from C, but from some point between S and C. The great convenience of the steelyard is its requiring only one weight. In a pair of common scales, a load of 10 lbs. must be balanced by a weight of 10 lbs. making together a load of 20 lbs.; but in the steelyard, a weight of 10 lbs. may be balanced with only 1 lb., making together a load of only 11 lbs.

In the *Danish balance*, Fig. 90, the fulcrum F is movable, instead of the counterpoise P, Fig. 89, which, in this case, is permanently fixed at one

extremity P, while the body to be weighed is placed in the scale pan at the other. If C be the centre of

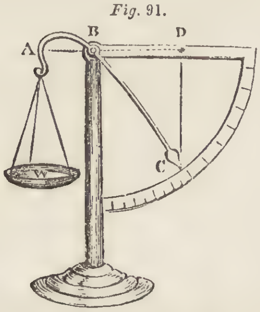
Fig. 90.



gravity of the unloaded beam, the graduation must commence from that point, because when the loop of the movable fulcrum is there, it poises the unloaded beam. By suspending from the hook at W, 1, 2, 3, &c. lbs. in succession, the divisions may be found to which the fulcrum must be removed in order to produce equilibrium, and the weight of the substance in the scale pan is indicated by the number of the point at which the fulcrum is placed when the instrument is in equilibrium.

The *bent lever balance* is made in a variety of forms, the principle of which will be understood from a common form shown in Fig. 91. It consists of a bent lever A B C, movable about an axis B. To one end of the lever, a constant weight C is fixed, and to the other end A, a hook with a scale-pan A attached, for containing the substance to be weighed. Through the centre of motion B, draw a horizontal line A B D, upon which, from A and C let fall perpendiculars; then if B A and B D are reciprocally proportional to the weights at A and C, they will be in equilibrio; but if not, the weight C will move upwards or downwards along the arc till that ratio is obtained. As the weight in W depresses the shorter arm B A, its leverage is constantly diminished, while that of the arm C B is constantly increased. When C counterpoises the weight, the division at which it settles on the graduated arc expresses its amount. The graduation, of course, commences at the point at which the index settles when there is no load in W.

Fig. 91.



[See also WEIGHING MACHINES, WEIGHTS and MEASURES, and WATCH.]

BALCONY. (Italian, *balco* or *palco;* French, *balcon.*) An open gallery projecting from the front of a building, and surrounded by a rail or balustrade of various devices, and supported by cantalivers, brackets or columns. A balcony may be constructed of wood, iron, or stone. Cast-iron is sometimes used, and at other times bar-iron fashioned into crail work of various figures. Balconies are generally made on a level with the sills of the windows of the first floor, and the windows are generally brought down to the floor. Sometimes a portico or porch is surmounted with a balcony, in which case the balustrade may be of stone, iron, or wood.

BALLAST. (Anglo-Saxon, *be-hlæstan,* to lade a ship.) The heavy materials, stone, gravel or iron, placed in the hold of a ship, in order to make the centre of gravity correspond with the trim and shape of the vessel, so as to be neither too high nor too low; neither too far forwards nor too far aft. The object is to lade the ship so deep that the surface of the water may rise nearly to the extreme breadth amidships. She will thus be able to carry a good sail, incline but little, and ply well to the windward. Iron ballast is alone used in the Royal Navy, but in merchantmen it is of various kinds, and masters are obliged to declare the quantity they bear, and to discharge it at certain places. Many excellent ports have been ruined by ballast being discharged in havens, roadsteads, &c. A ship is said to be *in ballast* when it has no other loading. For the regulations respecting ballast the reader is referred to McCulloch's Dictionary of Commerce, 1850.

BALLISTIC PENDULUM. [See PENDULUM.]

BALLOON. [See AËROSTATION.]

BALSAMS. The juices of certain trees and shrubs, capable of being applied to useful purposes in medicine and the arts. Balsams contain in general benzoic or cinnamic acid, with a volatile oil, and resins of variable consistency. They consequently vary in substance, thickening by degrees, and sometimes becoming entirely solid. The term balsam is by some writers confined to those juices which contain benzoic acid with a volatile oil and resin; while such as contain only resin and volatile oil are called turpentines or oleo-resins. This would exclude the balsams of Gilead, Copaiba, &c., in which there is no benzoic acid; but in ordinary language these continue to be ranked among the true balsams, the principal of which are the balsams of Peru and Tolu, benzoin, storax, and liquidamber. Peru balsam is obtained from a branching elegant tree (*Myrospermum Peruiferum*), growing in Peru, New Granada, &c., and is imported in two states, one called white, the other black. The former is the spontaneous exudation from the tree, the latter the result of boiling the bark and branches. The black balsam is the ordinary form. It is imported from Valparaiso in canisters or earthen pots, is of the consistence of treacle, and on account of its high price is extensively adulterated with turpentine, copaiba, or volatile oil. 1,000 parts genuine black balsam ought to saturate 75 parts pure carbonate of potash. Black balsam is fragrant, and is therefore employed as a perfume for pomatums, sealing-wax, lozenges, &c., and occasionally for chocolate and liqueurs. Balsam of Tolu is obtained from a closely allied species of tree, if not from the same species as that which yields Peru balsam. It has the taste and odour of the white balsam of Peru, and its constituents are the same. These balsams scarcely differ, except that in Tolu there is a facility of becoming resinified, which does not exist in the other.

Benzoin, improperly called a gum, and known as Gum Benjamin, must rank among balsams and resins. It is quite insoluble in water, and is the hardened

and fragrant juice of a tree (*Styrax benzoin*, or *Lithocarpus benzoin*) growing in Sumatra, Borneo, &c. In commerce it is met with in cakes, the best of which are of a light yellowish or fawn-colour, with portions of an almond shape, whiter than the rest. This is from the younger trees, and is called *Benzoe amygdaloides*. The chief use of benzoin is in yielding benzoic acid, but it is also much employed in perfumery, and helps to give the peculiar fragrance to the incense burnt in Roman Catholic censers. It is likewise an ingredient in varnishes, for such articles as are liable to be much handled, its fragrance being evolved by the heat of the hand. For the same reason it is added to the spirituous solution of isinglass, of which court-plaster is made.

Storax belongs to the same natural family as benzoin, being the product of *Styrax officinalis*, a handsome shrub, a native of Syria, Italy, and most parts of the Levant, and common all over Greece and the Peloponnesus. The storax of commerce is obtained from Asiatic Turkey. It is procured by incisions in the bark of the tree, whence oozes a liquid resinous substance which hardens in tears about the size of peas, and these in masses, constitute the rare and valued *Styrax albus*. Various qualities are met with in commerce, but the ordinary kinds are largely adulterated with saw-dust and resin. Storax was formerly imported wrapped in a leaf under the name of reed or cane styrax, (*Styrax calamita*,) but the substance now so called is a black or brown article in powder or in grains, or in agglutinated lumps. Another kind common in the drug market is called liquid storax, and is a dark-coloured substance with a disagreeable odour, more resembling coal-tar than balsam. For medical purposes it is necessary to purify storax in alcohol, and distil before the balsam is used. There is another substance called Storax in commerce which is often confounded with this; but is the product of the *Liquidamber styraciflua*, belonging to the natural family *Balsamaceæ*. This fine tree grows in Mexico and the United States, and resembles our lesser maple. A fragrant resin exudes, but not very copiously, from incisions in the stem, and this becoming dry and opaque forms the *soft* or white liquidamber.

Among balsams or oleo-resins in which there is an absence of benzoic acid are the following. *Copaiba* or *Copaiva* Balsam obtained from various species of *Copaifera*, trees growing in South America. The balsam flows freely from the stem as a clear transparent liquid like olive-oil, but thickens afterwards. From it are prepared essential oil of copaiba, resin of copaiba, and copaivic acid, employed in medicine. The balsam is also used for making paper transparent, and for certain kinds of lacquering. *Mecca Balsam* is the produce of a shrub (*Amyris Gileadensis*) growing at Gilead in Judea. It is turbid when fresh, but becomes clear and transparent by degrees. Chinese varnish and Japan lac varnish, whose names betoken their origin, are both valuable varnishes. The former is soluble in alcohol and ether, the latter in oil.

BALUSTRADE. (Latin *balustrum*, a space in the ancient baths that was railed in.) A range of small columns or *balusters* supporting a cornice and used as a parapet or a screen to conceal the whole or a part of the roof. Balustrades are also employed on the margins of stairs, or before windows, or to inclose terraces or balconies by way of security; or to separate one place from another, as around altars, fonts, or on the sides of the passage way of bridges. The word is sometimes improperly spelt *banister*.

BANDANAS. [See Calico Printing.]

BARBERRY. (*Berberis.*) A family of plants bearing acid fruit, and giving its name to the natural order *Berberidaceæ*. The common barberry is a graceful shrub, well known in England as well as in most temperate climates. De Candolle speaks of it as extending from Candia to Christiana; but neither this species nor any other of the family has been met with in Africa, Australia, or the South Sea Islands. In northern latitudes the barberry affects the valleys, in southern the mountains; it is found on Mount Ætna at the neight of 7,500 feet. In North and South America it is well known, and has been observed far south, near the straits of Magellan.

The fruit of this shrub is a cluster of drooping berries, of a beautiful coral red. Owing to the oxalic acid they contain, these berries are very sour, but they form with sugar an agreeable preserve, for sweetmeats, tarts, &c., and an excellent jelly. A cooling drink is made from them for invalids, and they are also pickled with vinegar, as a garnish for dishes. But it is on account of the yellow colouring matter and astringent properties of the stem and bark that the barberry has a place in our pages, for these make it useful as a dyeing material. The root is also bitter and styptic, and is used in Poland to give a yellow colour to leather. An Indian species (*Berberis tinctoria*) has a similar reputation for yielding a good yellow colouring material, and also furnishes a decoction which is said to give relief in cases of ophthalmia. The colouring matter is found in the whole of the root, but in the stem it is only deposited round the pith and near the bark; the great bulk of the woody fibre contains no colour. As the natives of India are skilful in making extracts, it has been suggested, that the colouring matter be sent to England in that form, and without the additional weight of the woody fibre. The colour is quite as good as that of the European root which we import from Cologne and Hamburg. Siberian barberry is known among the Mongol Tartars as Yellow-wood, and is applied by them to superstitious as well as medicinal uses. There are several varieties of the common barberry, differing but little in general character, but varying in the appearance of the fruit. Besides the well-known red-fruited, there are the white or yellow-fruited, the stoneless, the violet, purple or black-fruited, and the sweet-fruited, erroneously so called, for it is scarcely less acid than the common barberry, with which it agrees in the colour of the fruit, but the leaves are shining and of a brighter green. This variety is found wild in Austria.

The Barberry is interesting to naturalists on account of a remarkable property of its stamens. The irritability of these organs is such, that when the point of a pin is lightly applied to the filaments, they bend forward towards the stigma, and afterwards partially rise again. Experiments, with different powerful agents, have been tried, and it is found that this irritability is destroyed by poison. Arsenic and corrosive sublimate render the filaments too stiff and brittle to act, while prussic acid, opium, and belladonna make them too relaxed and flaccid. From these curious facts, it is inferred that there is in plants something analogous to the nervous system in human beings, and that in both cases it is more highly developed in some individuals than in others.

The barberry is infested by a minute fungus or blight, (*Æcidium berberidis,*) which fixes on the tenderest parts, and scatters, from thousands of small tubular openings, the orange-coloured dust which is so commonly seen on the leaves and flowers of this plant. This dust consists of a countless multitude of sporules, and it is their presence, doubtless, which has given rise to the idea that the barberry communicates blight to wheat fields. The *rust* which infests corn is indeed of the same colour as the barberry blight, but it is quite a different fungus, and the one can never propagate the other. Supposing, therefore, that there are any grounds for the popular opinion as to the injurious nature of barberry bushes to wheat, these are yet unexplained, and cannot be assigned to the presence of the parasite.

BARGE-BOARDS. The inclined projecting boards placed at the gable of a building, and hiding the horizontal timbers of a roof. They are frequently carved with various ornaments.

BARGE-COUPLES are two beams mortised and tenoned together for the purpose of increasing the strength of a building.

BARGE COURSE. The part of the tiling which projects over the gable of a building, and which is made good below with mortar.

BARILLA. [See SODA.]

BARIUM. The metallic basis of baryta. It may be obtained by strongly heating baryta in an iron tube through which the vapour of potassium is conveyed. The potassium combines with the oxygen of the baryta, and reduces the barium, which may be extracted by mercury and distilling the amalgam in a small green-glass retort. Barium is a white metal with the colour and lustre of silver; it is malleable, fuses below a red heat, decomposes water and oxidizes in the air. Its equivalent is 68.55, and its symbol is Ba.

The oxide of Barium, BaO, called baryta or barytes, occurs abundantly in nature as carbonate and sulphate, forming the vein-stone in many lead mines. Pure baryta may be obtained by decomposing the crystallized nitrate at a red heat. The baryta is a greyish spongy mass, fusible at a high degree of heat. It forms a hydrate with water, with great elevation of temperature. The hydrate is a white soft powder, which has a great attraction for carbonic acid, the smallest trace of which renders its solution instantly turbid. Water, saturated with carbonic acid, dissolves $\frac{1}{820}$th part of baryta, forming what is called *baryta water*, which is a useful test for carbonic acid. Of all the bases, baryta has the strongest affinity for sulphuric acid, and is, therefore, used either in the state of baryta water or in that of one of its neutral salts, as the nitrate or muriate, to detect the presence and determine the quantity of that acid in any soluble compound. The peroxide of Barium, BaO_2, has not much interest in the useful arts, and indeed, the whole subject of this article belongs rather to scientific chemistry. The sulphate of baryta, or heavy spar, BaO, SO_3, is used as a pigment under the name of *permanent white*, but chiefly for the purpose of adulterating white lead; but as it does not form a body with linseed oil, its presence is injurious. Sulphate of baryta, on account of its cheapness and weight, is also employed in other cases of adulteration. The native sulphate was employed by Wedgwood in the manufacture of *jasper ware*, and for the production of opaque white patterns and figures upon a coloured ground. The specific gravity of the native sulphate is as much as 4.7, and that of baryta is about 4; hence its name, as being the *heaviest* (βαρὺς, heavy) of the substances usually called *earths*. Nearly all the barytic compounds are poisonous, but the sulphate of baryta is harmless; the best antidote, therefore, for the soluble barytic salts, is a solution of sulphate of soda.

BARK. The outer rind of plants, which in some cases yields an astringent principle called *tannin*, highly useful in medicine and the arts. The most important kinds of bark in a commercial point of view are undoubtedly Oak-bark and Peruvian bark. Oak-bark was for a long time the only substance used in England for tanning leather, and is still preferred before all other substances, although larch-bark has come into extensive use. Oak-bark is powerfully astringent, and would probably have remained the sufficient and only tanning material, had there not been a failure in the supply, which induced a search after other substances, and led to those experiments of the scientific of former days, and latterly of Sir Humphry Davy, by which several other barks yielding tanning materials were brought conspicuously into notice. Davy has ascertained the relative value of various substances in this respect, showing that $3\frac{1}{2}$lbs. of oak-bark are equal to $2\frac{1}{4}$lbs. of galls, to 3lbs. of sumach, to $7\frac{1}{2}$lbs. of the bark of the Leicester willow, to 11 lbs. of the bark of the Spanish chestnut, to 18 lbs of elm-bark, and to 21 lbs. of common willow-bark. The importation of common oak-bark has somewhat declined of late years, but is still very considerable from Belgium, Holland, Germany, Italy, Spain, Norway, and Australia. There is a kind of oak-bark imported from the United States, called Quercitron, the produce of the *Quercus tinctoria*, used in tanning, and also in giving a yellow dye to silk and wool. The colouring matter obtained from this bark is equal to that obtained from eight or ten times its weight of weld. The useful properties of

Quercitron were discovered and applied by Dr. Bancroft, who patented his invention in 1775. In the parliamentary returns of the quantity of oak-bark imported into this kingdom, there is no distinction made between oak-bark for tanning and dyeing purposes. The quantity imported in the year 1842, was upwards of 639,429 cwt.; and the duty amounted to 13,400*l.* The proportion of tannin in oak-bark varies greatly with the season in which it is cut, and with the age of the tree. Young trees barked in spring yield by far the largest amount. The operation of barking is thus performed:—When the tree is felled, and before it has been deprived of its larger branches, the whole are stripped of their bark by women called *barkers*, each furnished with a light short-handled mallet made of hard wood, the face of which is about 3 inches square, and the other end sharpened like a wedge. With the sharp part an incision is made along the side of the tree in a straight line, while cross-cuts are also made with a pointed instrument called the *barking-bill.* A shovel-shaped instrument called a *peeling-iron* is then forced between the bark and the wood, separating the former without difficulty in entire pieces. These are carefully dried for two or three weeks, and then piled in stacks and sold to the tanner.

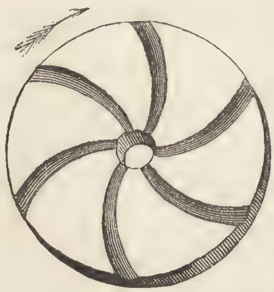
Next in importance to oak-bark, is the Peruvian or Jesuits' Bark, well-known as a valuable medicine. Of this there are three principal species, known in commerce as *pale, red,* and *yellow* bark. The first is the produce of *Cinchona lancifolia,* and is the original cinchona of Peru. It is received in chests covered with skins, each containing about 200 lbs., consisting of pieces 8 or 10 inches long, and singly or doubly quilled, or rolled inwards. It is of a pale fawn or cinnamon colour, and has very little odour while dry, but the decoction is agreeably aromatic. The taste is a fine bitter, but austere. This species is becoming more and more scarce. The second, or red bark, is obtained from *Cinchona oblongifolia,* growing on the Andes, and is received in chests weighing from 100 to 150 lbs. each. This kind is mostly in flat pieces of various sizes, with occasionally some that are quilled; the internal part being woody, and of a rust red colour. Red bark has a weak peculiar odour, and a less bitter, but more nauseous taste than the other barks. The third, or yellow bark, is the produce of *Cinchona cordifolia,* growing in Quito and Santa Fé. The chests contain from 90 to 100 lbs. each, in pieces from 8 to 10 inches long, some quilled, but the greater part flat. The interior is yellow approaching orange-colour. It has nearly the same odour in decoction as the pale, and has a more bitter and less austere taste. If the colour of the specimen be variable, it is not of the first quality, and if it be dark between red and yellow, it should be rejected. The medical uses of Peruvian bark are said to have been first discovered by the Jesuits. This important substance was brought to Europe in 1632, but was not much used till the latter end of the seventeenth century. Humboldt estimates the quantity now annually exported from America at from 12,000 to 14,000 quintals. In the pale Peruvian bark there exists a principle called *cinchonia,* and in the yellow bark an analogous but distinct principle called *quinia,* both of which are obtainable by a somewhat expensive process, and are abundantly prepared for medical use. The valuable properties of the bark are thus available in a concentrated form. Sulphate of Quinia or Quinine is now an object of especial attention, and is manufactured both in this country and on the continent to a very great extent. The annual export from Paris alone, is estimated at 120,000 ounces.

BARLEY. An important grain for malting purposes, but a bad bread corn: "*Grossier comme pain d'orge*" is a French proverb. Barley is extensively cultivated in most temperate climates, and is even raised within the tropics, but not at a lower elevation than about four thousand feet. The principal sowing season in our own country is in March or April, according to the situation. This crop generally follows turnips, potatoes, or pulse, and is important in the rotation adapted to light soils. It seldom follows wheat and oats, unless after three ploughings, and then only under certain circumstances. The produce varies, according to season, situation, and preparation of the soil, from 20 to 60 or 70 bushels per acre. From 30 to 40 bushels is a usual crop. The nutritive matter obtained from barley is reckoned at 65 per cent.; that of wheat at 78 per cent. A bushel of barley, weighing 50lbs., will consequently contain about 32lbs. of nutriment. The barley crop is of great importance in England, and occupies the ground about four months. The best barley counties are the middle line of counties from east to west. In Egypt and similar genial climates two crops of barley may be raised in the same year; one in spring, from seed sown the previous autumn, and one in autumn, from a spring sowing. By the hail which desolated Egypt during the sojourn of the children of Israel "the flax and the barley were smitten: for the barley was in the ear, and the flax was bolled. But the wheat and the rye were not smitten: for they were not come up."—Exod. ix. 31. This event is computed to have happened in the month of March, at which time the first crop of barley was nearly ripe, and the flax ready to pull. But the wheat and rye sown in spring were not sufficiently forward to receive injury.

Pot barley is barley deprived of its outer skin. Pearl barley, also called Scotch or French barley, is barley deprived not only of the skin, but of a portion of the grain, leaving merely a small round kernel. Both preparations are made by means of the same kind of mill, but the pearl barley receives a greater degree of the grinding process. The grain is kiln-dried before it is ground. The simplest form of mill, and that which is now in use on the Continent, resembles a common flour-mill, with two mill-stones, each about three feet in diameter, one fixed, the other revolving over it. The upper stone has six grooves cut in the lower surface, from the centre to the circumference (Fig. 92), and a perforation in the centre. It revolves on a vertical axis of iron, the lower point of which moves in a metal cup fixed on an elastic horizontal beam.

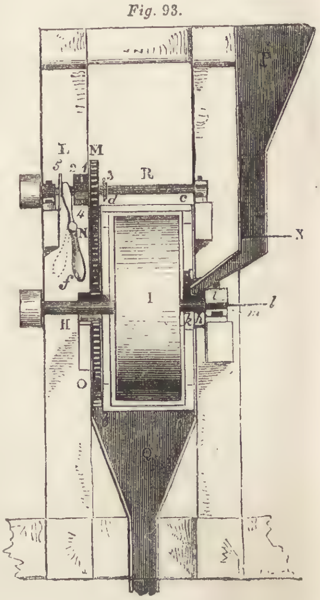
The upper stone moves parallel to the lower, and so close to it as to rub without crushing the grain which passes between them. The mill is fed by a hopper, through the central opening, as in the common corn-mill. The stones work in a cylindrical box or case, the top of which is of wood, with a circular opening corresponding to that of the stones. The circumference of the box is of thin iron plates, punched with numerous holes, so as to resemble a nutmeg-grater, the rough surface of which is within, and assists the operation of removing the skin from the barley. Before being placed in the hopper, the barley is slightly moistened with water, and turned two or three times, in order to loosen the skin; it is tnen gradually supplied by the hopper to the action of the stones: it enters the grooves in the upper stone, and is whirled round at the rate of two or three hundred revolutions per minute, thus breaking the skin, and strongly rubbing, but not crushing, the grain against the under stone. It is then driven off with considerable force against the grating surface of the cylinder, which, together with the current of air produced in the process, completely removes any remaining skin from the grain. From the cylinder it is let out through a square opening, and falls on a sieve, where the naked barley is separated from the bran. The greater part of the fine particles of barley escape through the holes in the cylinder during the process; therefore, to avoid waste, a cloth is fastened round the cylinder, and guides the meal into a bin below. This mill answers very well for pearl barley, but for simply removing the skin, or making pot barley, it has these disadvantages,—that it requires great nicety in the adjustment of the stones, and that, with every precaution, the barley is ground unequally, the larger grains losing more of their substance than is desirable.

Fig. 92.



The supply of pearl barley to this country, and indeed to the rest of Europe, was formerly a Dutch import; hence it was called Dutch pearl barley; but at present the manufacture is largely carried on within our own dominions, and we receive the larger portion of our pot and pearl barley from Scotland. The mill commonly used in that country consists of one ordinary grindstone, such as cutlers use, revolving on a horizontal axis, passing through the centre of an outer case, shown in section *a b c d,* and entire in Fig. 94, which moves at a slower rate, by the means shown in Fig. 94. The outer case is moved by a pinion M fixed to the spindle R, at the opposite end of which is a drum, connected by an endless band with the moving power. The stone I is also moved by a similar contrivance. The pinion M is fixed to the spindle R by means of a brass bush fitted into the centre of the pinion, and then bored exactly to fit a conical place in the spindle R. Below the base of the cone is a brass ring 3, to keep the pinion M firm upon the cone by means of four screw-bolts which bring the pinion firmer to the base of the cone. On the other side the pinion are two projections or snags, 1, which take into similar projections on the end of the catch 2 5. This catch slides along the spindle R by moving the lever N, but goes round with the spindle by means of two tongues fixed on the opposite sides of the spindle, one of which is partly visible at 4. Two grooves are cut in the inside of the catch, to admit the tongues, in order to carry the catch round with the spindle. The wheel N O, having 102 teeth, and a diameter of 4 feet $1\frac{1}{8}$ inches to the pitch stroke, is screwed to the sides of the drum that incloses the stone. This drum, which is shown in section *a b c d*, is lined with milled iron, pierced with small holes, in order to permit the escape of the dust, and to act as a grater to the barley.

Fig. 93.



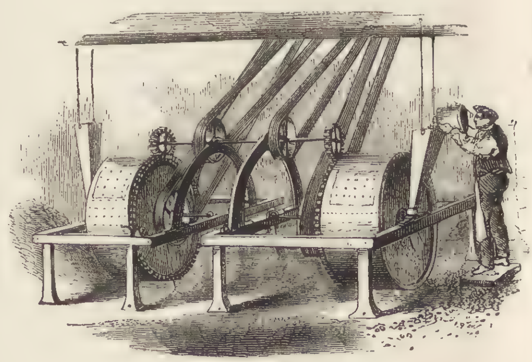


Fig. 94.

When the drum is turned round by the wheels already described, it is supported and kept clear of the stone by the collars *h i*. The collar *h* is larger than *i*, in order to give room to the spout P, to fill the drum with barley. This is effected by a thin plate of iron *k*, about an inch larger in diameter than the inside of the collar, which is kept close to the side of the collar next the stone by the staple *l* on each side of the stone spindle. The other end of it is kept fast by the cover of the pillow-block *m*. In the plate *k* a hole is cut for the end of the spout. When the barley is made, the drum is stopped by

pulling the lever N towards *f*. A small sluice which is upon the side of the drum, Fig. 94, is then opened, and the barley is allowed to run off into the trough Q. When the drum is thus emptied, the sluice is shut, and the lever N is moved back, by which means the wheel M engages with the spindle R by the catch 2 5, and the sluice X being opened, the drum is filled with fresh barley. When this machine is set in motion, the barley is so thoroughly tossed and beaten between the stone and the case, owing to the double motion, that it is entirely deprived of its skin, and, if the process be continued, it also loses a further portion of its substance, and becomes pearl barley. By means of this machine three bushels of barley may be converted into pot barley in an hour, and into pearl barley in two hours.

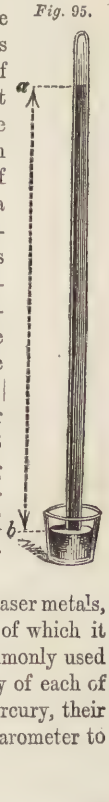
BARM. Another name for YEAST, probably from *bæren*, to raise. See BEER.

BAROMETER. The application of this word, from βάρος, weight, and μέτρον, a measure, is not very appropriate, the common balance being rather a measurer of weight than this instrument, which merely indicates or measures the variations in the pressure of the atmosphere. The barometer is one of the most valuable instruments ever contrived for assisting the philosopher in searching out the laws of the wonderful ocean of air in which we live, and its invention belongs to a highly interesting period in the history of science. Some time previous to the year 1643, a pump was sunk at Florence for the purpose of raising water from an unusually great depth, when, upon working it, it was found that the water would rise no higher than about 32 feet. Galileo was consulted, but he did not explain the phenomenon satisfactorily. After his death, his pupil, Torricelli, who had long meditated on the subject, devised the following experiment, in the year above mentioned. He took a glass tube, about 4 feet in length, closed at one end and open at the other, and, having filled it with mercury, closed the open end with his finger, inverted it, and placed the open end below the surface of mercury contained in a basin. Holding the tube in a vertical position, he withdrew his finger, and observed that the mercury sank in the tube a certain distance, and, after a few oscillations, settled at the height of about 27½ inches above the surface of the mercury in the basin.[1] On comparing the height of the column of mercury with the height of the column of water raised by the pump, he found these heights to be in an inverse ratio of the specific gravities of the water and mercury. Observing also that the columns of water and mercury had no communication with the atmosphere at their upper extremities, but that they did communicate therewith at their lower extremities, he concluded that the two columns were suspended by the same cause, namely, the weight or pressure of the atmosphere.

In 1646, Pascal at Rouen verified Torricelli's experiment, and also varied it by employing liquids of different specific gravities; he found that the lighter the liquid, the greater the height of the column in the tube. But, as the effect of an invisible fluid like the air in supporting a column of so ponderous a fluid as mercury was still doubted, Pascal suggested a complete *experimentum crucis* by observing the height of the column of mercury supported at the bottom, and at the top, of a considerable elevation. Two tubes filled with mercury were conveyed to the mountain Puy de Dome, near Clermont, in Auvergne. At the base they both stood at 28 inches; one was left there, and the other taken to the summit. As the observers ascended, the mercury in the tube sank gradually to 24.7 inches, and as they descended, the mercury as gradually rose again to its former elevation. This result was exactly what Pascal had anticipated; for, if the cause which sustained the column in the tube were the weight of the atmosphere acting upon the external surface of the mercury in the basin, then it was to be expected that on taking the tube to the top of a mountain, a gradually diminishing quantity of atmosphere would be above it, and the column of mercury sustained by the weight of this incumbent atmosphere must undergo a corresponding diminution in height. The experiment was repeated by Pascal himself, with similar success, by taking one of the tubes to the top of a high tower in Paris. It was further observed that by keeping the tube for a length of time in a fixed position, the height of the column was found to vary from day to day within certain small limits: an effect which could only be ascribed to fluctuations in the weight of the atmosphere itself.

The simple apparatus devised by Torricelli, consisting of a tube of mercury dipping into a cistern of the same metal, is in fact the barometer. Although this instrument has been distorted into endless varieties of shape, and with numerous additions, yet they have been abandoned one after the other, and the simple form in which Torricelli first observed the effect of atmospheric pressure in sustaining a column of mercury, has long been admitted to be the best form of apparatus for noting the daily and hourly fluctuations in that pressure. There are, however, certain precautions necessary to be attended to, both in the filling of the tube and in making observations.

Fig. 95.



The essential parts of a good barometer are a well-formed glass tube, Fig. 95, 33 or 34 inches long, of equal bore, containing pure mercury; a cistern of mercury, for receiving the open end of the tube; and an accurately-adjusted scale, for ascertaining the exact height of the column.

The mercury must be purified from all baser metals, such as tin, lead, zinc, and bismuth, all of which it dissolves with facility, and which are commonly used as adulterants; for, as the specific gravity of each of these metals is much less than that of mercury, their presence would cause the height of the barometer to

(1) The vacant space thus formed between the top of the mercury and the top of the tube is called the *Torricellian vacuum.*

be greater than that of an instrument containing pure metal only. Mercury appears to be incapable of retaining either air or moisture, and the air-bubbles which rise from it when heated or relieved of atmospheric pressure are merely retained between the mercury and the glass vessel in consequence of the attraction existing between glass and air.

On pouring mercury into the barometer tube and inverting it, as in the Torricellian experiment, the film of air confined between the mercury and the inner surface of the tube, being relieved from pressure, will escape into the Torricellian vacuum, where it will by its elasticity oppose the pressure of the external air, and constantly maintain the mercurial column at a lower level than if the vacuum were perfect; so that the observed height of the column would indicate only the excess of the pressure above that within the tube. In order to get rid of this air, and any moisture within the tube, the mercury is introduced in small portions at a time, and boiled over a charcoal fire between each introduction, holding that part of the tube over the fire which contains the last portion of mercury introduced. The filling of a barometer tube requires many precautions, which are usually noticed in works devoted to the subject.[1] When the tube is properly filled, it is inverted into a cistern of pure mercury, and when the column sinks to the proper level, its length above the surface of the mercury in the cistern exactly counterbalances the atmospheric pressure, unless, indeed, we take into account the minute quantity of vapour of mercury which, above the temperature of 60°, rises into the Torricellian vacuum; but this is so slight a cause of deterioration that it may be neglected.

The precautions taken to ensure contact between the mercury and the interior of the tube cannot of course be used for the exterior, where the tube is surrounded by the mercury in the cistern. A film of air is always retained at this part of the tube, and also at its under edges, which film creeps by small portions at a time into the interior, and rises up in minute bubbles into the vacuum, the film being constantly renewed by the descent of more air between the outside of the tube and the mercury in the cistern. In this way the most carefully constructed barometers deteriorate in the course of years, as was shown by Professor Daniell, on a comparison of the registers of the celebrated Meteorological Society of the Palatinate.

In the register kept at Mannheim for twelve years, from 1781 to 1792, inclusive, the mean height of the barometer for the second six years is .062 inch lower than that of the first six years.

In the register kept at Padua during the same period, the mean of the last six years is .044 inch lower than that of the first six.

In the register kept at Rome, the average of the last six years is lower than that of the first by .114 inch.

At Buda the difference is .035 inch; at Brussels .044 inch; at Munich .026 inch; from the summit of Peisenberg, a mountain in Bavaria, .026 inch; and from the summit of Mount St. Gothard the depression is also .026 inch.[2]

This irregular and uncertain deterioration of barometers cannot be too greatly deplored, because it vitiates the observations of all those earnest and competent observers who during many years have devoted daily portions of their valuable time to a record of the oscillations of the barometer at various stations Indeed, until the defect complained of was remedied by Professor Daniell, the great mass of barometrical observations can scarcely be said to be of any scientific value. The remedy consists in welding a ring of platinum to the open end of the barometer tube, so as to bring it in contact with the mercury: by this simple means the ingress of air into the tube has been effectually prevented.

The same excellent man and distinguished philosopher also invented a new mode of filling barometer tubes, by screwing the tube into the under surface of the table of an air-pump, and making such arrangements as enabled him to fill the tube and also to boil the mercury in vacuo. For the details of this contrivance we must refer to the original essay; but it may be noticed, as a striking proof of the absence of air and the perfect contact of the mercury with the glass, that, although the bore of the tube was more than half an inch, yet, on inverting it, the mercury did not fall at once to its usual height, but remained suspended to the top of the tube, until detached therefrom by a few concussions.

The excellence of a barometer may be tested by the brightness of the mercurial column, and the absence of any flaw, speck, or dulness of surface; secondly, by what is called the *barometric light*, or flashes of electric light in the Torricellian vacuum, produced by the friction of the mercury against the glass, when the column is made to oscillate through an inch or two in the dark; thirdly, by a clicking sound produced by the mercury striking the top of the tube when the column is made to oscillate. If air be present it will form a cushion at the top, and prevent or greatly modify this click.

The sectional area of the tube is of no consequence to the height of the column of mercury supported. If the sectional area be equal to 1 square inch, the column of mercury 30 inches high will be counterbalanced by a column of atmospheric

(1) The construction of the barometer and its use as a meteorological instrument are described in detail in the Editor's "Treatise on Pneumatics," published in Weale's Rudimentary Series.

(2) Professor Daniell remarks:—"There is a defect which may often be observed in old looking-glasses, which may probably be referred to the same cause as the deterioration of barometers. I allude to a dulness which takes place in large spots over their surface, and which generally seems to radiate from the centre. I have frequently remarked this in the very old mirrors in some of the palaces upon the Continent. I imagine that this arises from the slow insinuation of air by the edges, or some accidental crack in the metal at the back of the glass." A damp wall will also produce a similar effect upon looking-glasses, the moisture probably favouring the entrance of the air. See "Elements of Meteorology," vol. ii. London, 1845. The two Essays on the Construction and Deterioration of Barometers are admirable specimens of patient research, which ought to be studied by every one interested in the subject.

air 1 inch square, and extending from the surface of the mercury in the cup *b*, Fig. 95, to the top of the atmosphere; and as we know the pressure of the air to be about 15 lbs. on the square inch, so the column of mercury 1 inch square in the barometer tube weighs about 15 lbs. If instead of mercury we take 15 lbs. of water, and form it into a column 1 inch square, we get in such case a height of about $32\frac{1}{2}$ feet. If the sectional area of the tube of the mercurial barometer be only half an inch, the column of mercury will still retain the same height, for it is counterbalanced by the same height of atmosphere, only the column of atmosphere has in this case a base of only half a square inch instead of an inch. So long therefore as the atmosphere presses with the same intensity upon the surface of the mercury in the cup, the column suspended in the tube will be of the same height whatever be its internal diameter.

It has been already stated that the height of the mercurial column *a b*, Fig. 95, must be measured from the surface of the mercury in the cistern. Now it will be obvious that the level of the surface must always change with the oscillations of the column. When the atmospheric pressure increases, and the mercury in the tube rises, a portion of the metal is drawn out of the cistern into the tube, and the level of the mercury in the cistern is depressed. So on the contrary, when the atmospheric pressure diminishes, a quantity of mercury is forced out of the tube into the cistern, and the level of the metal in the latter rises. If therefore the instrument be furnished with a fixed scale at the top of the column, graduated when the distance between the top of the column and the level of the mercury in the cistern is exactly 30 inches, it will be evident that when the top of the column sinks to 29 inches on the scale, the distance between the two extreme points will not be 29 inches, but somewhat less, depending on the capacity of the cistern. So also, if the column rise to 31 inches, the distance will be rather more than this, on account of the additional quantity of mercury drawn into the tube. If the cistern be a section of a cylinder with a flat bottom, bearing a certain known proportion to the bore of the tube, such as 1 : 100, and the mercury rise 1 inch above the neutral point, then as much mercury will be withdrawn from the cistern as fills 1 inch of the tube; but as the base of the cistern is 100 times greater than the bore of the tube, it is obvious that this inch of mercury in the tube would cause a fall of only $\frac{1}{100}$th of an inch in the level of the mercury in the cistern; or in other words, the fall of $\frac{1}{100}$th inch in the mercury in the cistern is accompanied by a corresponding rise of $\frac{99}{100}$ths in the tube. A similar effect is produced by any other change in the height of the column, so that if the inches on the graduated scale be made each $\frac{1}{100}$th part less than an inch, the instrument will afford tolerably correct results. In some instruments, however, the scale accurately divided into inches and parts of inches is made movable, and terminates in an ivory point which is brought down to the surface of the mercury. When this point and its reflection appear to be in contact, the height indicated by the scale is correct. In other forms of the barometer, the mercury in the cistern is always maintained at the same level, for which purpose the cistern is formed partly of leather, so that by means of a screw at the bottom the surface of the mercury may always be adjusted to the neutral point before taking an observation. The cistern is also sometimes provided with a gauge or float, which indicates when the mercury in the cistern is too high or too low. By turning the screw one way or the other, the mercury in the cistern is adjusted to the proper level. When there is no gauge, the relative capacities of the cistern and tube are ascertained and marked on the instrument together with the neutral point. In an example given by Mr. Belville,[1] the capacity for every inch of elevation of the mercury in the tube is supposed to be equal to $\frac{1}{40}$th, which reduced to a decimal = 0.025 inch for 1 inch; 0.013 inch for $\frac{1}{2}$ inch; 0.007 inch for $\frac{1}{4}$ inch.

		Inches.
Then if the observed height	=	30.400
And the neutral point be	=	30.000
The difference above the neutral point will be..		.400
Then add for capacity	+	.010
The correct height will be		30.410

In this case the observed height is above the neutral point. In the following example it is below it.

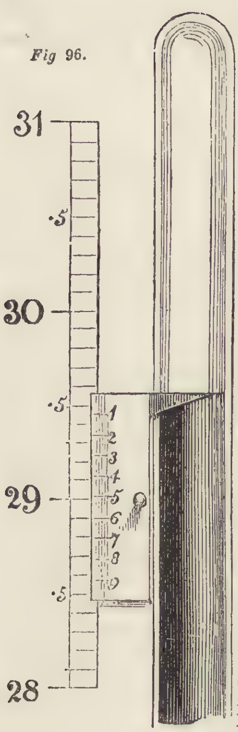
		Inches.
Observed height	=	29.500
Neutral point	=	30.000
Difference below neutral point		.500
Subtract for capacity	−	.013
Correct height		29.487

As the range of the barometer in this country is limited to about $3\frac{1}{2}$ inches, it is not necessary to commence the scale from the neutral point. The divisions usually begin at the 27th inch, and are continued to the 31st. But in instruments intended to measure the height of mountains, or for accompanying balloons, the scale begins at the 12th or the 15th inch. Each inch is divided into 10 parts, and these are subdivided into hundredths by means of a little sliding scale called a vernier or nonius[2] attached to the side of the large scale as in Fig. 96. It measures exactly one inch and one-tenth in length, and is divided into 10 equal parts numbered from the top downwards, while the divisions of the inches of the scale are numbered from the bottom upwards. Now as 10 divisions on the vernier are equal to 11 on the scale, and as those 10 are all equal to each other, it follows that each division of the former must be equal to $1\frac{1}{10}$ division of the latter, or to $\frac{11}{100}$th inch. If therefore any division on the vernier

(1) A Manual of the Barometer. By J. H. Belville, of the Royal Observatory, Greenwich. London, 1849. This cheap but excellent little work ought to be in the hands of every one who uses a barometer.

(2) So called from Peter Vernier, a gentleman of Franche Compté, who described it in a tract printed at Brussels in 1631. The word nonius is derived from Peter Nunnez or Nonius, as his name has been Latinised, a Portuguese Mathematician born at Alcazar in 1497.

Fig 96.



coincide, or is in a line with a division on the scale, the two lines immediately above or below those which coincide will be separated by a distance exactly equal to $\frac{1}{100}$th inch; the pair, two divisions removed from the first, has a deviation of $\frac{2}{100}$ths of an inch, and so on. Thus in Fig. 96, the line marked 6 on the vernier coincides with the line 28.9 on the scale, but the two lines immediately above them, marked 5 and 29, do not exactly coincide; and this want of coincidence must amount to $\frac{1}{10}$th of $\frac{1}{10}$th of an inch, or $\frac{1}{100}$th of an inch. In the next two lines, marked 4 and 29.1, it will be seen that they fail to coincide by $\frac{1}{10}$th of $\frac{2}{10}$ths of an inch, or $\frac{2}{100}$ths of an inch. In like manner the lines marked 3 and 29.2, 2 and 29.3, 1 and 29.4, and 0 and 29.5, deviate from each other respectively by $\frac{3}{100}$, $\frac{4}{100}$, $\frac{5}{100}$, and $\frac{6}{100}$ths of an inch. The same reasoning will also apply to the lines situated below the coincident lines marked 6 and 28.9. Thus 7 and 28.8 immediately below them fail to coincide by $\frac{1}{100}$th of an inch, and so on with respect to the others. The point to be attended to is that a division on the vernier is $\frac{1}{100}$th of an inch larger than a division on the scale.

In applying the vernier to measure off small fractions of an inch in the height of the barometer, we first notice the height of the column by the fixed scale, which in Fig. 96 is more than 29.5 inches, but less than 29.6. In order to measure the hundredths of an inch, we place the zero or top of the vernier scale exactly level with the top of the mercury; we next observe that of all the lines on the vernier only one can coincide with a line on the scale. In the figure the line marked 6 on the vernier coincides with a line on the scale; and as from the top of the mercury to these coincident lines there are six pairs which do not coincide, and as each pair deviates by $\frac{1}{100}$th of an inch more than the pair below it, the uppermost pair must evidently differ by $\frac{6}{100}$ths of an inch. We thus get the height of the mercury in our figure, which is $29\frac{1}{2}$ inches and $\frac{6}{100}$ths of an inch, or, expressed decimally, 29.56.

The words "Change," "Fair," and "Rain," engraved on the plate of the barometer, are calculated to mislead the observer; for, as Mr. Belville observes, "from the observations of two centuries we find that heavy rains and of long continuance take place with the mercury at 29.5 inches, or 'Change;' that rain frequently falls when it stands as high as 30 inches, or 'Fair;' and, more particularly in winter, a fine bright day will succeed a stormy night, the mercury ranging as low as 29 inches, or opposite to 'Rain.' It is not so much the *absolute* height as the actual rising and falling of the mercury which determines the kind of weather likely to follow." Instrument-makers still continue to engrave these words on the scale, apparently for no other reason than old-established usage; their customers would probably think the instrument imperfect without them, just as the readers of Moore's Almanack insist upon having the supposed influence of the planets upon the different members of the body entered for every day in the year. Indeed, the defects of the common barometer, as it leaves the hand of the instrument-maker, are so serious as to render this instrument almost worthless to science. "In the shops of the best manufacturers and opticians," says Professor Daniell, "I have observed that no two barometers agree; and the difference between the extremes will often amount to a quarter of an inch; and this with all the deceptive appearance of accuracy which a nonius, to read off to the five-hundredth part of an inch, can give. The common instruments are mere playthings, and are by no means applicable to observations in the present state of natural philosophy. The height of the mercury is never actually measured in them, but they are graduated from one to another, and their errors are thus unavoidably perpetuated. Few of them have any adjustment for the change of level in the mercury of the cistern, and in still fewer is the adjustment perfect. No neutral point is marked upon them, nor is the diameter of the bore of the tube ascertained; and in some the capacity of the cistern is perpetually changing, from the stretching of a leathern bag, or from its hygrometric properties. Nor would I quarrel with the manufacture of such playthings: they are calculated to afford much amusement and instruction; but all I contend for is, that a person who is disposed to devote his time, his fortune, and oftentimes his health, to the enlargement of the bounds of science, should not be liable to the disappointment of finding that he has wasted all from the imperfection of those instruments upon the goodness of which he conceived he had good grounds to rely. The questions now of interest in the science of meteorology require the measurement of the five-hundredth part of an inch in the mercurial column; and, notwithstanding the number of meteorological journals, which monthly and weekly contribute their expletive powers to the numerous magazines, journals, and gazettes, there are few places indeed of which it can be said that the mean height of the barometer for the year has been ascertained to the tenth part of an inch."

The barometer ought to be fixed in a truly vertical position, and, if possible, with a northern aspect, in order that it may be subject to as few changes of temperature as possible. It is usual, for the sake of comparison, to reduce the observations to 32°, for which purpose tables for correction for temperature are given in scientific works devoted to the subject of the barometer. "The height of the cistern of the

barometer above the level of the sea, and, if possible, the difference of the height of the mercury with some standard, should be ascertained, in order that the observations made with it should be comparative with others made in different parts of the country. Before taking an observation, the instrument should be gently tapped, to prevent any adhesion of the mercury to the tube; the gauge should be adjusted to the surface-line of the cistern, and the index of the vernier brought level with the top of the mercury." The best times of the day for observing the barometer are at 9 A.M. and 9 P.M., when it stands higher, and at 3 A.M. and 3 P.M., when it stands lower, on an average, than any other times during the twenty-four hours; as may be proved by examining a barometric register kept for a long period, and taking the average of each set of observations made at the same hour. In this climate, and in summer, the mean of a few weeks is sufficient to elicit this fact. As 3 A.M. is an inconvenient time for observations, a person with time at his disposal should select the other three hours for making his entries. If he can make only two observations, the proper periods are the convenient hours of 9 A.M. and 9 P.M. If he can make only one observation, then *noon* is the time. Professor Daniell remarks that those who merely consult the barometer as a weather-glass would find it an advantage to attend to the three above-mentioned periods, for he has noticed that by much the safest prognostications from this instrument may be formed from observing them when the mercury is inclined to move contrary to its periodical course. If the column rise between 9 A.M. and 3 P.M., it indicates fine weather; if it fall from 3 to 9, rain may be expected.

In the application of rules for prognosticating the weather, by observations made on the barometer, the most important fact to be remembered is, that the state of the weather to be expected is not so much connected with the absolute height of the column as with its motion, whether rising or falling. A fall in the mercury generally indicates approaching rain, high winds, or a thunder-storm; but snow is more frequently preceded by a rise than by a fall. With this exception, a rising state of the barometer commonly indicates the approach of fine weather. The lowest depressions occur with the wind at S. and S.E., when much rain falls, and frequently short and severe gales blow from these points. A N.E. wind is more conducive to a high state of the barometer than any other. When the mercury rises or falls steadily for two or three days together, it is generally found that rather a long continuance of settled weather will follow: rainy in the latter case, and fine and dry in the former. By the same rule, frequent fluctuations in the height of the column are found to coincide with unsettled weather.

In a tube of small bore, when the mercury is rising its surface is convex; when it is falling it is concave, as if the centre of the fluid column always preceded the sides in all its motions. In such a tube, in nice observations, a correction has to be made for capillarity. Corrections for temperature, which acts unequally upon the mercury, the glass of the tube, and the metal of the scale, are also made in accurate observations, and tables are provided for all these purposes.

The causes of the oscillations of the barometer are too intricate to be discussed within the limits of a short article, but the reader will find them stated at some length in the treatise on Pneumatics, in Weale's Rudimentary Series. When the barometer is used alone, it has a far more direct application to the theory of the winds than to that of rain, and with this view Mr. Belville has constructed the best set of rules we have ever seen, connecting the phenomena of the barometer with the direction of the wind, and also with the appearance of the clouds, according to Howard's nomenclature. These rules occupy 11 pages of Mr. Belville's little manual, to which we must refer. This work also contains a table showing the mean height of the barometer at noon for Greenwich, for every day in the year, deduced from 30 consecutive years' observations, viz. from 1815 to 1844, and reduced to 32° Fahr. The following are the monthly means from this table:—

January	29.909	second maximum
February	29.859	
March	29.857	second minimum
April	29.856	
May	29.884	
June	29.910	maximum
July	29.894	
August	29.890	
September	29.872	
October	29.851	
November	29.801	minimum
December	29.884	

The mean annual pressure for noon at Greenwich is 29.872 inches.

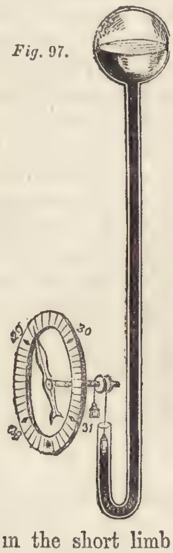
It appears from Mr. Belville's table, that "at certain seasons of the year, great periodic maxima and minima take place. The greatest daily mean pressure for the year occurs about the 9th January, and the minimum daily mean depression towards the end of November. It is a remarkable coincidence, that the lowest daily mean temperature for 30 years, occurs on the 8th and 9th of January, and the daily mean temperature for November rises suddenly 4° in the last few days in November."

From a table of the greatest and least observed heights of the barometer at Greenwich, between 1811 and 1848, it appears that the maximum elevation for the 38 years, occurred in 1825, when the mercury stood at 30.89 inches; in 1821 it reached 30.82 inches; in 1835, 30.84 inches, and in February 1849, 30.86 inches. In the extreme depressions those of 1821 and 1843 differ only by 21 hundredths; the first occurred on the 25th December, when a Troughton's mountain barometer sank as low as 27.89 inches. "A heavy rain of some hours' duration with the wind at south-east, had preceded the minimum pressure; a gale from the north-west followed, in which the mercury rose a few tenths. The depression of 1814, 28.21 inches, happened at

the close of the great frost, and was likewise preceded by a stormy wind from SS.E. and much rain."

The common wheel-barometer or weather-glass, is a contrivance for increasing the length of the scale. It has no scientific value, but as it is in very common use as a piece of furniture, some notice may be expected of it in a popular work. In this instrument the tube instead of terminating at the bottom in a cistern, is recurved so as to form an inverted syphon, as in Fig. 97. As a rise in the mercury in the longer or closed limb is equivalent to a fall in the shorter limb, and vice versâ, a float is placed on the surface of the mercury in the shorter limb, and is connected with a string passing over a pulley, and very nearly balanced by another weight on the other side. An index hand attached to the pulley moves over the surface of a dial plate, graduated so as to indicate the oscillations of the column. With an increase of pressure the mercury in the longer tube rises, and that in the short tube is depressed, together with the float, and this gives a small motion of revolution to the pulley and also to the index hand. A fall in the longer column causes the mercury with its float in the short limb to rise, and consequently moves the index-hand in the contrary direction. This barometer is very inferior to the vertical or cistern barometer, because a change of pressure such as would make a difference of nearly an inch in the upper level of the latter, would show but half an inch in each level of the syphon; for, although the surfaces of the mercury in the two limbs would be an inch further apart, that inch would be compounded of a rise of half an inch at one surface and a corresponding fall at the other. Our unit of measure, therefore, becomes only half as great, and necessarily diminishes in utility. In Fig. 97, however, the upper end of the tube is expanded into a bulb, in order that, by enlarging the upper surface of the mercury, the difference of level may be made to depend almost entirely on the lower surface, giving the same advantage as in a common barometer, with a cistern of the same horizontal area as the bulb.

Fig. 97.



For the measurement of heights, and as an instrument for accompanying the scientific traveller, barometers have been made portable. Fig. 98 represents Troughton's portable barometer, closed so as to protect the instrument and render it portable, and Fig. 99 shows it mounted on a tripod ready for use. The staff-head is constructed in a peculiar manner for the purpose of suspending the barometer. It consists of a circle, Fig. 100, about $\frac{3}{4}$ of an inch broad, joined in three pieces; the three joint-pins extend inwards so as to pass through a circular rim which they hold fast; within this rim is hung a similar one by two pivots; and within the latter, at right angles to the pivots, are fastened two angles, in which the barometer hangs by its gudgeons. By this ingenious arrangement, the legs of the tripod can be extended, and the instrument is supported by, and can be turned about on, a universal joint, on which it adjusts itself in a plane perpendicular to the horizon. The cistern, Fig. 101, is a glass cylinder about $2\frac{1}{2}$ inches in diameter and the same in length. An external brass tubing, terminating in an interior screw a little above and below the glass, admits external screw pieces whose ends, covered with leather, being pressed firmly against the ends of the glass, prevent the escape of the fluid. Near the upper end of the brass cover of the cistern are two horizontal slits opposite to each other, one before and the other behind. At the bottom is a screw, by turning which the leather bag is compressed and the mercury forced to the top of the tube, and thus filling every part, the instrument is rendered portable. This screw also furnishes the means of adjusting the surface of the mercury in the glass cistern, so as just to shut out the light from passing between it and the upper edges of the slits in the brass cover. This is the mode of adjusting to zero, the upper edges of the slits representing the commencement of the scale of inches. The frame is also of brass tube about $1\frac{1}{10}$th inch in diameter. The first 10 inches of the lower end is occupied by a thermometer, the bulb of which is bent inwards and concealed within the frame. At about three inches higher, it is attached to the stand by the ring, Fig. 100, in which the frames turn smoothly for the purpose of placing the instrument in the best light for reading off. The divided scale commences at 15 inches above the neutral point, and is continued as high as 33 inches, and by the help of a vernier is subdivided into the $\frac{1}{1000}$th of an inch. A longitudinal slit from end to end of the divided part, exposes the glass tube and mercury. The

Fig. 98

Fig. 99.

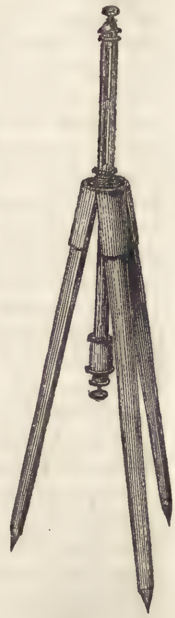


Fig. 100.

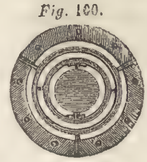
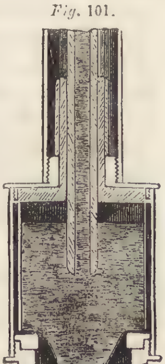


Fig. 101.

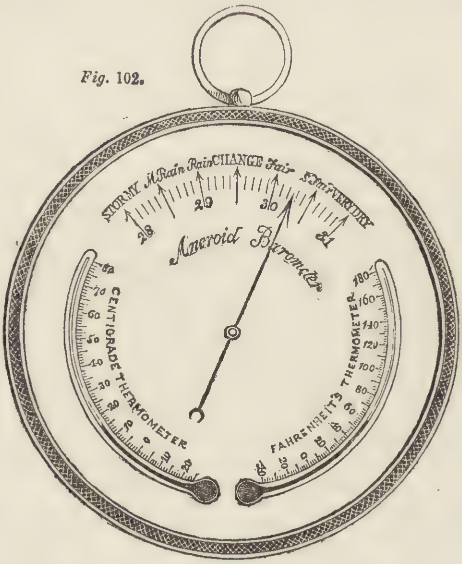


whole of this part is formed of two tubes of brass; in the inside of the interior one, a cylindrical piece slides, and on this is divided the vernier scale, the index to which is the lower end of the piece. In taking the height of the mercury, this piece is brought down by means of the screw at the top, so as just to exclude the light from passing between itself and the spherical surface of the top of the column of the mercury. The screw at the top acts upon the interior tube, within which the vernier piece is sustained by friction, and is first set by hand and then adjusted by the screw.

Soon after the invention of the barometer, attempts were made to construct a water-barometer, on the supposition that the greater range of its oscillations would measure more minute changes of pressure. The most perfect instrument of this kind was constructed by Professor Daniell, in the hall of the Royal Society at Somerset House. It consists of one entire tube of glass 40 feet long. Its diameter is about an inch, and the average height of the fluid column 400 inches. When originally erected in the year 1832, the water in the cistern was covered with a layer of castor oil; but as that did not prevent the admission of the outer air, it was found necessary to refill the tube. This was done in January 1845, and a solution of caoutchouc in naphtha was substituted for the castor oil. In windy weather, this barometer appears to be constantly fluctuating, indicating numerous changes of pressure, which have no sensible effect on the most delicate mercurial barometer; the column appears to be in a state of perpetual motion, similar to the slow act of respiration. But the most important result is, that this instrument precedes by one hour the mercurial barometer of half an inch bore, as this does the mountain barometer of 0.15 inch bore, by the same interval in their horary oscillations; showing that while scientific men are disputing about the hours of the maxima and the minima, much depends upon the construction of the instrument observed.

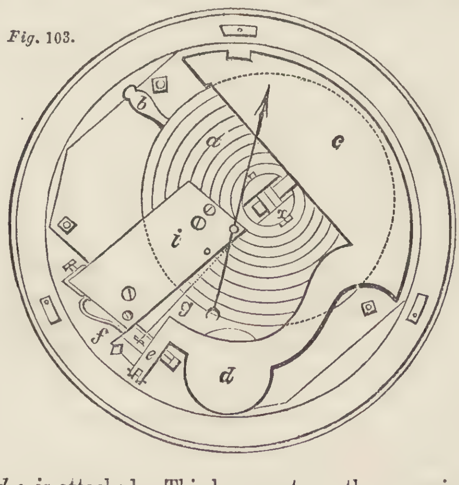
An instrument named the *Aneroid* Barometer, has lately been invented by M. Vidi of Paris. Its action (as described by Mr. Redwood, in the Pharmaceutical Journal) depends on the effect produced by the pressure of the atmosphere on a metallic box, from which the air has been exhausted, and then hermetically sealed. An index traversing a dial records the changes in the weight or pressure of the air on a given surface. It is 4¾ inches in diameter across the face, and 1¾ inch in thickness. It is graduated to correspond with the common barometer, and two small thermometers are fixed on the face of the dial. Fig. 102 represents the external appearance of the instrument, and Fig. 103 the internal construction as seen when the face is removed, but with the hand still attached. *a* is a flat circular box about ¼ inch in depth, made of some white metal, the upper and under surfaces of which are corrugated in concentric circles to give it greater elasticity. This box being exhausted of air through the short tube *b*, and then made air-tight by soldering, forms a spring which is affected by every variation of pressure in the external atmosphere. It is attached to the bottom of the

Fig. 102.



metallic case, which encloses the mechanism of the instrument. At the centre of the upper surface of the elastic box is a solid projection *x*, about half an inch high, to the top of which, the principal lever

Fig. 103.



c, d, e, is attached. This lever rests partly on a spiral spring at *d*, and is also supported by two vertical pins, with perfect freedom of motion. The end *e* of the principal lever is attached to a second or small lever *f*, from which a chain *g* extends to the centre, where it works on a drum attached to the arbour of the hand. A hair spring, the attachments of which are made to the metallic plate *i*, regulates the motion of the hand.

As the weight or pressure of the atmosphere is increased or diminished, the surface of the elastic box *a* is depressed or elevated, and this motion is communicated through the levers to the arbour of the hand. The spiral spring on which the lever rests at *d*, is intended to compensate for the effects of alterations of temperature on the minute portion of air

which the box must contain, however perfect the exhaustion. The actual movement at the centre of the elastic box, from whence the indications emanate, is very slight, but this is increased 657 times at the point of the hand; so that a movement to the extent of $\frac{1}{22}$d part of $\frac{1}{10}$th of an inch in the box, carries the point of the hand through 3 inches on the dial. The tension of the box in its construction is equal to 44 lbs. At the back of the outer case is a screw, to adjust the hand to the height of a standard mercurial barometer.

BARYTA. [See Barium.]

BASE, in geometry, is the lowermost part of a figure, and in a solid, the surface on which it rests.

The *base of a room*, is the lower projecting portion, consisting of two parts, a plain board adjoining the floor, called the *plinth*, and above it one or more mouldings, which, taken collectively, are called the *base mouldings*. The plinth ought to be tongued into a groove in the floor, by which the diminution of breadth, caused by the shrinking, does not produce any aperture between its under edge and the floor. The upper edge of the plinth ought to be rebated upon the base.

In chemistry, the substance with which an acid is combined in a salt, is called its *base*. Thus, in sulphate of iron, sulphuric acid is the acid, and oxide of iron is the base. The term *basyle*, is often applied to a body which gives to a base its distinctive character; thus ethyle, is the basyle of ether. The term *radicle*, is applied to a substance which gives to an acid its distinctive character; thus cyanogen is the radicle of hydrocyanic acid.

BASE-LINE. [See Geodesy.]

BASKET. A kind of vessel made of osier, wicker, rushes, straw, grasses, twigs, branches, whalebone, &c. of different figures and sizes, according to the purpose it is intended to serve. The ancient Britons were celebrated for their baskets, which were exported in large quantities, and fetched high prices in Rome. The art of interweaving twigs, reeds, &c. is practised among the rudest nations at the present day, and they even excel Europeans in this simple art. In some parts of South America, the natives make rush baskets so closely interwoven as to hold water. Wicker boats covered with skins attracted the notice of the Romans in Britain, and at the present day, basket boats made of split bamboo are used in Hindustan. Houses, cottages, fences and gates of wicker-work are used in different parts of the world. A two-horse carriage of basket-work called a "Holstein wagon," is used in some parts of Europe, and an appendage to stage-coaches, called the *basket*, was formerly made of wicker-work.

The most common substances used for basket-making are osiers or willows. Those of the best kind were formerly imported into Great Britain from France and Holland, but the trade having been interrupted during the long protracted war, the Society for the Encouragement of Arts and Manufactures offered a premium to those cultivators who should raise the greatest quantity, the number to be not less than 6,000 plants on an acre. Mr. Philipps of Ely was one of the successful competitors. According to him the osier, a species of salix, contains many varieties, which may be separated into two divisions, and in each division there is only one variety well adapted for basket-making. In the first division is the grey or brindled osier: this, in common with the others, has a light-coloured leaf, but is distinguished by the bark being streaked with red or blood colour. It grows vigorously, it is very hardy and tough, and bleaches well. All the other varieties are coarse and spongy; they have a thick pith and are very perishable. They are however still used for coarser work, and during the interruption of the continental intercourse were in great request; hence, English baskets fell into disrepute. In the second division is the *Welsh willow*, which is tough and durable but of a bad colour: there are two varieties, the red and the white, the former of which is preferred and forms part of every plantation, from its use in tying up the bundles after they have been barked or whitened. There are other varieties known as the *west country Spaniard*, the *new willow*, the *French* and the *red Kent willow*. The French is the best, especially for smaller and finer work in baskets, fans, hats, &c.: it is extremely taper, pliant, close-grained, tough and durable. Large quantities of it are imported into Great Britain from the continent.

According to Philipps, autumn, not spring, is the proper season for planting willows, and as early in autumn as the cuttings can be taken without injury to the parent stock. The ground is laid out in beds or burrows 18 feet broad with ditches 9 feet wide on each side. The upper surface of the ditches to the depth of 14 inches is thrown on the beds, and the remainder of what is excavated from them is used for turf or fuel. The beds, now consisting of about $2\frac{1}{2}$ feet thick of solid earth above the surface of the substratum of peat, are planted in the autumn, and produce good crops. The plants should not be supplied with too much water, or they will be sickly: they require a considerable degree of humidity, but will nevertheless flourish on comparatively dry soils. The vicinity of water is an essential quality in selecting a spot for a plantation. The sets of osiers should be inserted in regular rows: their age is not of importance, for a vigorous crop may be produced from the root of the oldest tree deprived of its trunk. When the plants have acquired their maturity they are cut and made up into bundles in iron hoops, 36 or 40 inches in diameter, for the market, and are sold in this way or in loads. The plantations require to be well fenced against cattle, which find a favourite food in the shoot and leaf.

In the preparation of osiers for the basket-maker, they are either split asunder or stripped of their bark, according to the kind of work in which they are employed. When stripped, the osiers require to be previously soaked in water, and the stripping is performed by drawing the willows through an iron edged machine called *brakes*, which removes the

bark; the osiers are then cleaned by a sharp knife. They are next exposed to the sun and air, and are stored in a dry place. The osiers which are not stripped, require to be carefully preserved, and before being used they must be soaked in water. The barked or white osiers are divided into bundles or faggots according to their size; the larger ones being used for the strong work in the skeleton of the basket, and the smaller for the bottom and sides. When the smaller osiers are used for ordinary work, they are taken whole, but for fine work each osier is divided into *splits* and *skains*. Splits are osiers cleft into four parts by an implement consisting of two edge tools placed at right angles, which divide the rod longitudinally down the pith. These are next drawn through an implement resembling the common spoke shave, keeping the grain of the split next the wood or stock of the shave, while the pith is presented to the edge of the iron, which is set in an oblique direction to the wood; and to make the split more regular, it is passed through an *upright* or flat piece of steel with a cutting edge like an ordinary chisel. The flat is bent round, so that the two edges approach at a greater or less interval, by means of regulating screws, and the whole is fixed into a handle. By passing the splits between the two edges, they are reduced to skains, the thickness of which is determined by the interval between the edges of the tool. The basket maker is furnished with a few simple tools, such as knives, bodkins and drills for boring, leads for keeping the work steady, and a heavy iron beater, for beating the work close as it increases in size.

Basket-work is a coarse kind of weaving, in which the long osiers form the warp, and those which are twined in, or interlaced therewith, the woof. In making an ordinary basket, the length of the osiers selected for the purpose is considerably greater than that of the finished work. The proper number is arranged on the floor in pairs parallel to each other, in the direction of the length or warp of the basket. These parallel rods are then crossed at right angles by two of the largest osiers, with the thick ends towards the workman, who places his foot on them, and weaving each alternately over and under the parallel pieces first laid down, they are thus confined in their places. In this way the foundation of the basket, called the *slat* or *slate*, is formed. The long end of one of the two rods is next taken and woven under and over the pairs of short ends all round the bottom until the whole is woven in. The same is done with the other rod, and then additional long osiers are woven in until the bottom is of sufficient size. The slat being thus finished, the superstructure is raised by first sharpening the large ends of as many long and stout osiers as are required to form the ribs or skeleton. These are forced or plaited between the rods of the bottom, from the edge towards the centre, and are turned up in the direction of the sides. Then other rods are woven in and out between each of them until the basket is raised to the intended height. The edge or brim is finished by turning down the projecting ends of the ribs whereby the whole is firmly and compactly united. A handle adapted to the work is formed by forcing two or three osiers, sharpened at the end, and cut to the

Fig. 104.

proper length, down the weaving of the sides close together, and they are pinned fast about two inches from the brim, so as to retain the handle in the proper position. The osiers are then bound or plaited, and the handle is finished.

Such are the simple processes concerned in making an ordinary basket. Other baskets differ only in having finer materials and nicer workmanship. The skains are frequently smoked and dyed either in dull or brilliant colours, and the taste of the workman is shown in their proper mixture.

The facility of teaching and acquiring the art of basket-making, renders it a favourite employment for the blind in the asylums established for their reception.

The bine of the hop, with the flowers and leaves removed, has been lately employed as a material for basket-making or wicker-work. A patent was taken out by Mr. Reynolds, in 1847, for this employment of an article previously considered useless.

BASSORINE. [See Gum.]

BATHS. Places constructed purposely for the washing of the body in hot, cold, or tepid water, a practice, the salubrity of which was well understood by the ancients, as it is by some modern nations, but which has been greatly overlooked in our own country until very recently, when it has begun to be better appreciated, and to receive something like a due share of attention. It is scarcely to be wondered at, that eastern nations should exalt ablution and bathing to the rank of religious observances, for where the heat renders perspiration copious, frequent bathings are not only means of pleasure and refreshment, but absolute and necessary duties of life. And even in cold, or in perpetually varying climates like our own, although bathing cannot be so freely indulged in, especially by invalids, yet the functions of the skin cannot be preserved in healthful activity, nor the

changes of climate effectually guarded against, without the frequent use of the bath. A clever writer on Physiology says, "The warm, tepid, cold, or shower bath, as a means of preserving health, ought to be in as common use as a change of apparel, for it is equally a measure of necessary cleanliness. Many, no doubt, neglect this, and enjoy health notwithstanding; but many, very many, suffer from its omission, and even the former would be benefited by employing it."

At Athens, and in Rome, baths were in common use; in the latter, during the Augustan age, they were so luxuriously built and furnished, as to call forth the reproof of philosophers. According to Seneca, private baths were constructed with the utmost magnificence, so that even among plebeians, that person was held to be poor, or sordid, whose baths did not shine with costly marbles and precious substances, enclosed within richly decorated walls, and supplied with water from silver pipes. The public baths were at least sixteen in number, and of great magnitude and beauty, containing large halls for bathing and swimming, others for athletic games, others for public lectures and conversations. All these fine rooms were lined and paved with marble, and furnished with paintings, statuary, collections of books, &c. These baths were called *Thermæ*, which means "warm waters," and are now all in ruins. The suite of rooms more immediately appropriated to bathing, included an *apodyterium*, or room for undressing; an *unctuarium*, for the ointments; a *sphæristerium*, or room for exercises; a *calida lavatio*, or warm bath; a *laconicum*, or hot room for sweating; a *tepidarium*, or warm room with a tepid bath; and a *frigidarium*, which contained the cold bath. The public baths of Rome were constructed at a vast expense, and principally for the use of the poorer classes, though frequently resorted to by all ranks: they were named after the emperors, and those of Titus, Diocletian, and Antoninus Caracalla, are still in sufficient preservation to give a tolerable idea of their former grandeur. The last named were 1,500 feet long, by 1,250 broad, and at each end were temples, one to Apollo, the other to Esculapius, the tutelary deities of the place.

It is a gratifying feature of our own times, that the care for the health and comfort of the working and poorer classes, which was long ago exhibited by a heathen nation, has now taken deep root among ourselves, so that the erection of public baths and washhouses is a matter in which numbers of influential persons feel a lively interest. The first attempt of this sort in the metropolis, appears to have been that of a society of small means, established in 1844, and called an "Association for promoting Cleanliness among the Poor," which commenced operations in Glasshouse Yard, near the London Docks, and met with such success, as to lead to the formation of a more important association, and eventually to the bringing in of a Bill in Parliament, for the furtherance of the object. Since that time, several large establishments have been opened, in which private baths, both hot and cold, and also swimming baths, can be enjoyed at a very low charge; and where, in another department, the wives and daughters of labouring men are allowed to wash, dry, and iron their linen, at the rate of a penny an hour, and with conveniences and accommodations they had previously little notion of. This system has been also extended to the provinces, and it is not uncommon in manufacturing districts, to find special provisions made for the work-people in this respect, by their enlightened and benevolent masters. Contemporaneously with this increased attention to means of bathing for the lower classes, there has been a greater desire for accommodation of the same kind in the dwellings of the rich. Modern houses, not only of the first, but of the second and third class, now frequently include a bath-room, where the means of enjoying a warm bath are afforded, without much trouble to the inmates.

In the construction of baths several materials are employed, according to the taste and means of the proprietor. The best is undoubtedly marble, in the form of slabs, properly imbedded in cement, and forming a lining to a wooden case. This is expensive, and also weighty, and, if of white marble, is liable to get discoloured in time; but it is a very handsome and permanent kind of bath. Sometimes Dutch or earthenware tiles embedded in cement are used instead of marble, and answer very well if they can be kept water-tight, which is difficult. A very general material for baths is however found in either copper, zinc, or tinned iron. These are covered with several coats of paint and marbled. As a substitute for a better kind of bath, wooden tubs are sometimes used, but these soon contract a mouldy smell, and are also troublesome from their liability to shrink. The proper situation for a bath must be regulated by the convenience of the owners, but it is very desirable not to place it in the basement story, on account of a chilly and damp feeling which nearly always pervades the lowest rooms of a house. Yet this situation for the bath is not unfrequently chosen. In the better class of private houses, warm-baths are situated in the dressing-rooms adjoining the principal bed-rooms, or there is a separate bath-room on the bed-room floor. This should have proper means of ventilation, or a damp odour will soon be observed, and the walls will suffer from the moist atmosphere. Many modern houses possess the great convenience of a water cistern at the top, supplying the rooms without labour. In this case the bath is easily and adequately supplied, and if there happen to be a laundry at the upper part of the house, or convenient place for erecting a copper, this, by means of feeding pipes, would supply hot water to the bath. Another contrivance consists in carrying a pipe from a higher level than the bath-room down to the kitchen, and allowing it to repose in a coil within the boiler, from which the pipe is continued, and ascends to supply the bath. The cold water contained in the coiled part of the pipe becomes sufficiently heated by lying in the boiling water to supply a warm-bath; but it is

only when the boiler is kept hot by a large fire that this is found to answer. Sometimes a boiler is placed behind the fire-place in the dressing-room; but this is objectionable, from the escape of steam which sometimes takes place, and from danger of the flues becoming choked with soot and taking fire. Another and safer method is the following:—"A wagon-shaped boiler, holding about six gallons of water, is properly placed over a small furnace, in any convenient and safe part of the house, as the kitchen, scullery, servants'-hall, or wash-house. The bath itself, of the usual dimensions and construction, is placed where it is wanted, with a due supply of cold water from above. Two pipes issue from within an inch of the bottom of the bath, at its opposite extremities: one at the head of the bath, about one inch, and the other at the foot, an inch and one-eighth in diameter. These tubes descend to the boiler, the smaller one entering it at the bottom, and the larger one issuing from its top. Under these circumstances, supposing the pipes and boiler everywhere perfectly tight, when the bath is filled, the water will descend into, and expel the air from, the boiler, and completely fill it. Now, upon making a gentle fire under the boiler, an ascending current of warm water will necessarily pass upwards through the larger pipe which issues from its top, and cold water will descend by the pipe which enters at the bottom; and thus, by the establishment of currents, the whole mass of water in the bath will become heated to the desired point, or, if above it, the temperature may easily be lowered by the admixture of cold water." The quantity of fuel required for this kind of bath is very small, as is the time occupied in heating it; but two or three things have to be observed in using it. As soon as the water is sufficiently hot, the fire should be put out, or there may be an unpleasant increase of heat while the person is in the bath. Care should also be taken never to make so fierce a fire under the boiler as to cause the water in it to boil; for, in this case, the steam rising to the top, and condensing in the pipe, occasions violent concussions, which are very apt to injure the pipes, while they also cause alarm to the inmates of the house.

Baths are sometimes heated by steam; but this is more suitable for public than private establishments. Tinned iron or copper baths are also sometimes constructed with an outer case, in which water flows, and is made hot from a furnace at one end, thus heating the whole mass within the bath. The simplest of all contrivances for large establishments is that first alluded to, and which may be employed on a very large scale. A large boiler connected with the cistern, placed above the level of the baths, affords the means of drawing hot water in any quantity directly into the baths. Hot water should enter the bath by a pipe of $1\frac{1}{2}$ inch diameter, and cold water the same; and every bath should have a 2 inch waste-pipe, opening about two inches from the top of the bath, so that when the person is immersed, or the pipes are inadvertently left open, there may be no danger of an overflow.

BATTEN. A scantling of stuff from 2 to 6 inches broad, and from $\frac{5}{8}$ths to 2 inches thick. Battens are used in walls to secure the laths over which the plaster is laid. Before fixing the battens, equidistant bond timbers are either built in the wall, or the wall is plugged in equidistant points. The plugs are generally placed at the distance of 1 foot or 14 inches from centre to centre in the length of the batten. Battens upon exterior walls, quarters in partition walls, the ceiling and bridging joists of a naked floor, also the common joists for supporting the boarding of a floor, are fixed at the same distance, namely, from 11 to 12 inches in the clear. When battens are fixed against flues, iron holdfasts are employed instead of bond timbers or plugs. When attached to a wall, they are generally fixed in vertical lines. Great care should be taken to regulate the faces of the battens, so as to be as nearly equidistant as possible from the intended surface of the plaster. The act of fixing battens to walls is called *battening*, but in floors it is called *boarding*. Every piece of masonry or brick work which is not sufficiently dry should be battened for lath and plaster. When the windows are boarded, and the walls of a room not sufficiently thick to contain the shutters, the surface of the plastering is brought out, so as to give the architrave a proper projection, and quarterings are used for supporting the lath and plaster instead of battens. The same is also done when the breast of a chimney projects into the room, in order to cover the recesses, and make the whole side flush, or all in the same surface with the breast.[1]

BAY-SALT. [See SALT.]

BEAM, in building, is a piece of timber or metal used for sustaining a weight or counteracting two equal and opposite forces, either drawing or compressing it in the direction of its length. When employed as a lintel, it supports a weight; when used as a tie-beam, it is drawn or extended; and, as a collar-beam, it is compressed. "The word beam is most frequently subjoined to another word, used adjectively, or in apposition, which shows the use, situation, or form of the beam: as *tie-beam, collar-beam, dragon-beam, straining-beam, camber-beam, hammer-beam, oinding-beam, girding-beam, truss-beam, summer-beam*, &c. Some of these are also used simply, as *collar*, instead of collar-beam; *lintel*, instead of lintel-beam; *girder*, instead of girding-beam; *summer*, instead of summer-beam. Lintels and girders are almost constantly used simply, and *bressummers* and *joists* are never used in composition."—*Nicholson.*

BEAVER. [See HAT.]

BEER. At nearly all periods in the world's history, and among nearly all nations, the art of making a fermented drink from some kind of grain appears to have been known. Of all the cereals, barley is best adapted to the making of beer, and it is curious to notice how early this experimental fact was discovered. Herodotus, who wrote about 450 years B.C., states that the Egyptians made their *wine*, as he calls it, from barley, because they had no vines.

(1) Nicholson's Architectural Dictionary.

The Greeks also called their beer *barley-wine*. Dioscorides describes two kinds of beer made from barley. Tacitus states that, in his time, beer was the common drink of the Germans, as it is at the present day. Pliny says, that all the nations of the west of Europe make an intoxicating liquor of corn and water. "The manner of making this liquor, is sometimes different in Gaul, Spain, and other countries, and is called by many various names; but its nature and properties are everywhere the same." Isidorus and Orosius, describe the mode of manufacture adopted by the ancient Britons and other Celtic nations:—"The grain is steeped in water and made to germinate, by which its spirits are excited and set at liberty; it is then dried and ground, after which, it is infused in a certain quantity of water; which being fermented, becomes a pleasant, warming, strengthening, and intoxicating liquor." A better definition of beer could scarcely be given at the present day.

The curious and even complicated processes of brewing, have thus been in operation during several thousand years, but it has only been within our own time that chemical science has enabled us to comprehend them. It will be seen by reference to the article Bread, that most seeds contain a considerable portion of the well-known nutritive substance Starch or *fecula*. When seeds begin to germinate, a peculiar azotised substance named *diastase* (from διΐστημι, I separate) is formed, which possesses the remarkable property of converting the starch into a fermentable sugar resembling cane-sugar, but not identical therewith. This change does not, however, immediately take place, for the starch is first changed into a gummy mucilaginous substance, largely soluble in water, named *dextrine*, from the action of its solution upon a ray of polarised light, in causing the plane of polarization to turn to the right, while a solution of common gum causes a deviation in the opposite direction. Dextrine does not ferment by the addition of yeast; but by the action of diastase, it is readily converted into starch sugar, which is fermentible.

Preparatory to the process of brewing, the barley is converted into malt by being made to germinate up to a certain point, at which the proportion of diastase is largest; the vitality of the young plant is then destroyed by heat. The operation of a high temperature also serves another useful purpose, for it has been found that when starch is carefully heated up to a point when vapour rises from it, it loses its gelatinous character and becomes converted into dextrine. In the kiln-drying of malt, a portion of the starch, therefore, undergoes this change. In the first process of brewing, namely, infusing or *mashing* the malt with hot water, the starch or dextrine of the grain is converted into sugar by the action of the diastase, the quantity of which, in malted barley, scarcely exceeds 1 part in 500. A solution of diastase has no remarkable action on most vegetable principles, but on starch it exerts a specific action, converting it first into dextrine and afterwards into starch-sugar. The change of starch into dextrine by the action of diastase, takes place in gelatinous starch even at the freezing point of water; but the conversion into sugar is most powerful between 150° and 160°. At the boiling point of water, diastase ceases to act on starch. So powerful is the action of diastase at proper temperatures, that 1 part is said to be sufficient to saccharify 2000 parts of dry starch; but the larger the proportion of diastase the quicker the change. Thus, Messrs. Payen and Persoz, by the action of diastase, converted starch into dextrine or sugar according to the temperature of the mixture and the duration of the process. In a mixture of from 6 to 10 parts of pale malt, 100 of starch, and 400 of water, the starch was converted chiefly into dextrine, in from 20 to 30 minutes, at the temperature of 158°; but at the temperature of 167° the starch was almost entirely converted into sugar in the course of 2 or 3 hours.

These details throw great light upon the ancient arts of malting and brewing, and will, doubtless, assist the reader in following the practical details which we are now about to enter upon.

The principal substances concerned in the manufacture of beer are two; the one to form the sugar, and consequently the alcoholic portion of the liquor; the other to communicate a particular flavour, and also to assist in its preservation. The experience of mankind has led to the choice of barley for the first object and hops for the second. But instead of barley, any of the cereals, such as wheat, oats, maize, rice, &c., are fitted for the purpose, in consequence of the quantity of starch contained in them, and occasionally other vegetable bitters are substituted for hops.

There are two species of barley, *Hordeum vulgare* and *Hordeum hexastichon*. In the first or common barley, two seeds are arranged in a row on its spikes; and in the other, three seeds form a point, so that its double row has apparently six seeds. It is a hardy plant, better adapted to cold climates than common barley; it is largely cultivated in Scotland under the name of *bear* or *big*. The finest barley is grown in mild climates, and hence the barley of Norfolk and Suffolk has a denser and larger grain and a thinner husk than that of Scotland. When barley is converted into malt, a change takes place, which is represented in the following comparative analysis by Dr. Thomson. 100 parts of barley and 100 parts of malt contain respectively—

	In 100 of Barley.	In 100 of Malt.
Gum	5	14
Sugar	4	16
Gluten	3	1
Starch	88	69
	100	100

But according to Proust, barley also contains a peculiar substance, not soluble in hot water, which he terms *hordein*, and which during malting is diminished in quantity and converted into starch or sugar. Hitherto, hordein appears to have been

confounded with starch. His comparative analyses are—

	In 100 of Barley.	In 100 of Malt.
Resin	1	1
Gum	4	15
Sugar	5	15
Gluten	3	1
Starch	32	56
Hordein	55	12
	100	100

Hops are the seed pods of the female plants of the *Humulus lupulus*, a creeping plant of the family Urticeæ. It is cultivated in considerable quantities in Kent, Sussex, and Hampshire. The active part of the plant called *lupulin*, which is alone useful in making beer, is a yellow aromatic dust occurring at the base of the hop-flowers or cones. It consists of an essential oil, a resin, an azotised substance, sulphur, silica, chloride of calcium, sulphate and malate of potash, phosphate and carbonate of lime, and oxide of iron. This powdery secretion forms $\frac{1}{8}$th of the weight of the flowers. It can be easily collected by drying the flowers at the temperature of about 86° and shaking them in a coarse canvass bag. Of the complicated analysis of this dust, the volatile essential oil, which forms 2 per cent. of the total weight of the hop, is the most essential part.

The cones are gathered before they are scarcely ripe, for which purpose the plants are cut about 3 feet from the ground, and the cones carefully picked off one by one. Those that are too ripe or defective, are separated from those that are just ripe enough, and both kinds are carried to the kiln as soon as possible after they are picked. The heat of the kiln must be carefully regulated, to prevent the essential oil from being evaporated. The heat should not exceed 86° Fahr. In many cases the kiln has two floors, on the uppermost of which the greener hops are spread and gradually dried before they are subjected to the greater heat of the lower floor. Charcoal is the only kind of fuel which is found not to injure the flavour of the hops. They are considered sufficiently dry when they become crisp; but their brittleness is removed by allowing them to re-absorb a little moisture in the storehouse before being packed. 5 lbs. of moist hops weigh only 1 lb. when taken from the kiln. The good qualities of the hops can only be retained by excluding them from the air, for which purpose they are strongly compressed by means of a hydrostatic press, and packed in sacks of fine canvass called *pockets*, which weigh about $1\frac{1}{2}$ cwt. each. The stronger and darker coloured hops are packed in coarse canvass *bags* weighing about 3 cwt. The former are used chiefly by the ale brewer, and the latter by the porter and beer brewer.

The number of acres of hops in England, in 1848, was 49,232; the number of pounds weight charged with duty, was 44,343,985; 357,029 lbs. of British hops were exported, and 32,218 lbs. were imported and retained for home consumption. The Excise duty on British hops is 18*s.* 8*d.* per cwt. and 5 per cent. extra; the Customs duty on Foreign hops is 45*s.* per cwt.[1]

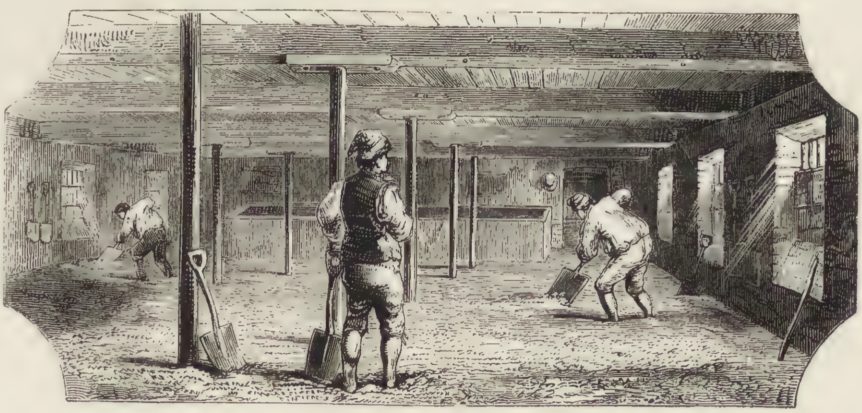


Fig. 105. STEEPING, COUCHING, AND FLOORING MALT.

The conversion of barley into malt is generally a distinct occupation from that of brewing. It consists of four processes, namely, *steeping*, *couching*, *flooring*, and *kiln-drying*. In the first process the barley is thrown into a square cistern lined with stone, and sunk at one end of the malt barn, Fig. 105. It is placed as evenly as possible upon the floor of the cistern, and a quantity of water is let in sufficient to cover it. The water is often introduced before the barley, and it is customary to draw off this water and introduce fresh during the steeping, to prevent anything like fermentation. The law requires that the barley shall remain in the cistern at least 40 hours, but in cold weather a much longer period is often required.

During the steeping, the barley imbibes moisture and increases in bulk; it also evolves carbonic acid, nearly all of which remains in solution in the water; a portion of the husk or skin of the grain also becomes dissolved, thereby imparting a yellow colour and a particular odour to the water. The quantity of water absorbed by the grain depends upon the goodness of the barley, and the time employed in

(1) Companion to the Almanac. 1850.

steeping. Dr. Thomson states the general average to be 0.47; or 100 lbs. of barley steeped the usual time, weigh, when taken out of the steep and dried, 147 lbs. English barley acquires more weight than Scotch barley, and this more than big. While the barley is in the steep cistern it is gauged by the exciseman, and the duty on the malt is levied by what is called the best gauge, or that which gives the greatest bulk of grain. Dr. Thomson has known Suffolk barley to swell from 100 to 183. This was the greatest he ever observed; the smallest was from 100 to 109, which took place in Perth big.

As the steep-water becomes of a yellow colour, the grain becomes whiter. and so soft that the two ends of a grain can be squeezed together between the finger and thumb. The water is then let off, and the grain allowed to drain. It is then thrown out of the cistern upon the malt floor, and arranged in a regular rectangular heap called the *Couch.* Here it is again gauged by the exciseman, and if it measure more than it did in the steep, he can charge an increased duty. The grain remains in the couch about 26 hours, during which time it gradually increases in temperature, and parts with its moisture. In about 96 hours after being thrown out of the steep, it is about 10° higher than the temperature of the surrounding air. It exhales an odour resembling that of apples; it feels warm and moist if the hand be thrust into it. This moisture is called *sweating,* and on examining the grains in the interior of the heap, it will be found that germination has commenced. Small roots appear at the bottom of each seed, having at first the appearance of a white prominence, which soon divides into three or more rootlets, which rapidly increase in length unless means be taken to check their growth, and in doing so consists the principal art of the maltster. The temperature is lowered, and the growth of the roots checked by the operation of flooring or spreading the grain thinner upon the floor, and turning it over carefully several times a day (see Fig. 105), so as to keep it at the temperature of about 62°. For this purpose the depth of the layer, which at first is 16 inches, is diminished a little every time the grain is turned, till at length the depth is only 3 or 4 inches. About a day after the sprouting of the roots, the rudiments of the future stem, called by the maltsters *acrospire,* begin to appear. It rises from the same extremity of the seed with the root, and advancing within the husk would, if the process were continued, at length issue from the other extremity in the form of a green leaf, but the process is stopped before it has made such progress. During this process the grain absorbs oxygen, and emits carbonic acid; and the temperature rises to about 70°, and in some cases even to 90°. The appearance of the kernel or mealy part of the corn undergoes considerable change. The glutinous and mucilaginous matter in great measure disappears, the colour becomes whiter, and the texture so loose that it crumbles to powder between the fingers. When the acrospire has come nearly to the extremity of the seed, the process is stopped, and the object of malting has been accomplished. The time usually occupied in this process of couching is about 14 days.

The germination of the malt is stopped by drying upon a kiln, which consists of a chamber, floored with an iron plate full of holes, and furnished with a vent in the roof for the escape of fumes. Below this floor is a furnace containing charcoal or coke, and the heated air ascends through the holes of the floor, and then through the malt, as in Fig. 106.

Fig. 106. THE MALT KILN.

The malt is first heated to about 90°, and then slowly raised to 140° or higher. The more rapid the drying of the malt, the greater is its bulk, and as malt is sold by measure, it is to the interest of the maltster to dry it quickly; but the time allowed ought to be about two days. When the fire is withdrawn, the malt is allowed to remain until it is nearly cold. In this process the roots of the grain, or *cornings,* as the maltsters term them, dry up and fall off, and are separated by allowing the malt to fall from the floor above through shoots, the ends of which are represented in the ceiling of Fig. 107, into a wire screen, the wires of which are set too close to allow the grain to pass through. To delay the progress of the malt down this screen, boards are placed crosswise at a short distance from the wires; and the workman, by agitating the malt with a stick,

further assists the separation of the radicle. The malt is then spread out to *mellow*, or to become soft and mealy by a slight absorption of moisture.

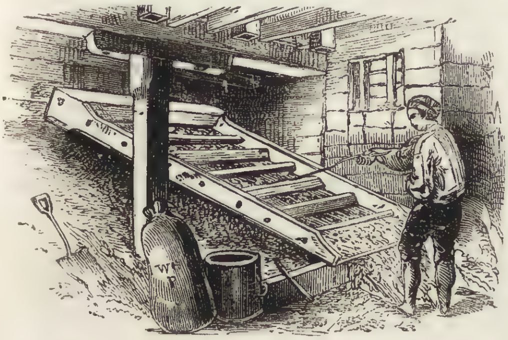


Fig. 107. CLEANING MALT.

After this malting, drying, and cleaning, Dr. Thomson found that 100 lbs. of barley originally employed will weigh on an average 80 lbs.; but if the raw grain be kiln-dried at the same temperature as the malt, it will lose 12 per cent. of its weight. Hence the real loss of weight sustained by barley in malting amounts to 8 per cent.; which is thus accounted for:—

Carried off by the steep-water . . .	1.5
Dissipated while on the floor . . .	3.0
Roots separated by cleaning . . .	3.0
Waste	0.5
	8.0

The waste arises from grains of malt crushed by the workmen while turning the malt on the floor. Big sustains a much greater loss of weight when malted than barley.

The bulk of the malt is greater than that of the barley from which it is obtained, but the amount varies with the goodness of the grain, and the method of kiln drying. According to the same authority, 100 bushels of the different kinds of grain gave on an average the following results:—

English barley	109
Scotch barley	103
Scotch big	100.6

Good malt should be large, clean, plump, and unshrivelled in the grain; the skin should be thin, and the grain should be lighter than water. The acrospire should be seen to extend scarcely more than three-quarters through the length of the husk. The grains should break without difficulty, and disclose a full, flowery, mellow kernel, which if drawn across a board, leaves a chalky trace. No part of the kernel should be hard or horny. The taste should be sweet and mellow. The colour is pale and bright, and the odour agreeable.

The quantity of malt made between Oct. 10, 1847, and Oct. 10, 1848, was for England, 4,193,757 quarters; for Scotland, 504,533 quarters; Ireland, 214,914 quarters. Total 4,913,204 quarters. The total quantity used in the same period was 3,699,771 quarters.

The varieties of malt known as *pale, amber*, and *brown*, can be produced from the same kind of malt by varying the temperature of the drying. Pale malt is dried at the proper temperature, and produces the strongest and best beer. Amber coloured malt is scorched, and in brown malt the scorching is carried to its utmost limit. Indeed this scorching is so wasteful a process, that where the object is only colour, it is better to mingle amber or brown malt with pale malt in proportions adapted to the required tint. The distinction between the terms *ale* and *beer* or *porter*, arose from the colour of the malt used in brewing, pale malt having been used for the former, and brown malt for the latter. The brown malt from its partial charring had acquired a bitter taste, which it communicated to the beer together with a dark colour, and being agreeable to the palate, and less exciting than ale, it became the favourite beverage of the common people, especially in the metropolis.[1] But when heavy taxes were imposed upon malt, the brewers discovered that a much larger quantity of wort of a given strength could be prepared from pale malt than from the brown. The consequence was that porter changed its character; for it was brewed from pale malt, and coloured with brown malt; while to imitate the pleasant agreeable bitter of the genuine porter, quassia, cocculus indicus, and other substances were employed. By the act 56th Geo. III. c. 58, no brewer is allowed to use or have in his possession any substance whatever for the purpose of darkening his worts or beer, except brown malt; nor is he allowed to mix with his worts or beer any molasses, honey, liquorice, vitriol, quassia, cocculus indicus, grains of paradise, Guinea pepper or opium, or any article or preparation whatsoever, for, or as a substitute for malt or hops, under the penalty of forfeiture and 200*l*. for each offence, and any person selling the same to a brewer for such purpose is liable to a penalty of 500*l*. By the act 1st Will. IV. c. 51, for repealing the ale and beer duties, the use of unmalted corn or grain, with malted, is forbidden under a penalty of 200*l*.

Brewing consists of six processes, namely, *grinding the malt*, *mashing* or infusing with hot water, *boiling* the wort with the hops, *straining*, *cooling*, *fermenting* with the addition of yeast, and *clearing*, storing, &c.

The malt should be ground, or rather crushed into a coarse powder, for if finely ground like flour, the hot water would cause it to set or coagulate into lumps, and thus prevent a large portion of it from being wetted at all. Two horizontal circular stones, such as are used in grinding flour, are sometimes used, but

(1) According to Malone, before the year 1730, the malt liquors in general use in London were *ale*, *beer*, and *twopenny*, and it was customary for the drinkers of malt liquor to call for a pint or tankard of half-and-half, that is, a half of ale and half of beer, a half of ale and half of twopenny, or half of beer and half of twopenny. In course of time it also became the practice to call for a pint or tankard of *three threads*, meaning a third of ale, beer, and of twopenny; and thus the publican had the trouble to go to three casks, and turn three cocks for a pint of liquor. To avoid this inconvenience and waste, a brewer of the name of Harwood conceived the idea of making a liquor which should partake of the same united flavours of ale, beer, and twopenny. He did so, and succeeded, calling it *entire* or *entire butt;* and as it was a very hearty and nourishing liquor, it was very suitable for *porters* and other working people. Hence it obtained the name of *porter*.

it is not possible to regulate the distance between them, so as to prevent some of the grains from being ground to flour, while others escape almost untouched. Steel mills which cut the grains by means of teeth something like coffee mills are also used; they are preferable to mill-stones, but grind the malt too much. The best contrivance is a pair of case-hardened iron rollers, regulated at such a distance apart, that the grains in passing through them are bruised only, not cut or ground.

The water being heated to about 160° or 170° in a large copper, is drawn off into a mash tun situated at a lower level. When the water has cooled down to about 160° or under, a quantity of crushed malt is shaken in, sufficient to absorb nearly the whole of the water when thoroughly stirred up with long poles called oars, or by means of stirrers within the mash tun moved by machinery (Fig. 109). The quantity of water ought to be sufficient thoroughly to wet the malt, and to cause it to swell considerably, so as completely to dissolve the sugar formed during the malting, and to allow the diastase to re-act upon the starch, which until now has remained unchanged. It has even been recommended to use the first portion of water at so low a temperature as 140°, in order to prevent any thing like coagulation in the starch. When the first water has thoroughly saturated the malt, and been left to repose for about half-an-hour, a second quantity of water at 194° may be introduced, and the mixture well stirred up. This mixture of water at 140° and 194°, forming a mean temperature of 167°, is most favourable for the action of the diastase. The mash tun should be covered up and left during two or three hours. The clear infusion of *sweet wort* as it is now called, is then drawn off into a vessel called an *underback*, situated at a lower level than the mash tun. This first infusion having carried off the greater portion of the sugar, and saccharified nearly all the starch; the temperature of the water for the next or *second mash* as it is called, may be as much as 194°. This, mingling with the cooled malt, is reduced to 176°. When this infusion is drawn off, it is added to the first.

108. THE STOKE-HOLE.

Fig. 110. THE COPPER.

Fig. 109. THE MASH TUN.

In the third mash, the water, which is near the boiling-point, removes all the remaining soluble matter, and leaves in the mash tun the ligneous pellicle or husk of the malt, a portion of coagulated albumen, and some foreign insoluble matters. This third infusion is not usually added to the first, but it is used for making small beer, or for wetting new malt.

The quantity of water employed for mashing depends, of course, on the greater or less strength of the worts. After the wort is drawn off, the malt retains about 32 gallons of water for every quarter of malt used. In the subsequent boiling and evaporation from the coolers 40 gallons of water are dissipated for every quarter of malt, making 72 gallons loss of water in all; so that if 13 quarters of malt be taken to make 1,500 gallons of beer, 2,400 gallons of water will be required for mashing.

In order that the wort may flow off clear, the mash tun is furnished with a false bottom, raised a few inches above the ordinary wooden bottom of the vessel, and composed of metal plates, lying closely together, and fitting the tun perfectly all round. These plates are perforated with numerous funnel-shaped holes, the widest part being downwards, and the hole in the upper surface too small to allow the grain to pass through. The cock for draining off the wort, or *setting the tap* as it is called, is placed in the tub between the two bottoms.

The first wort ought to be of the colour of the malt from which it is extracted; of a heavy sweet taste, and more delicate in flavour than the succeeding

worts, because the water was not sufficiently hot to bring away the coarser and more disagreeable parts of the grain. On this account the first wort is sometimes reserved for superior ales, and the second and third for inferior beers.

In order that the brewer may be able to brew beer of the same quality, it is necessary for him so to regulate the strength of his worts, or in other words, the quantity of saccharine matter in the same measure of water, that they may be at all times identical. As the same weight of malt does not always afford the same quantity of sugar to the worts, he mingles the worts of the different mashes, according to certain proportions which are indicated to him by means of an instrument called a *saccharometer*, which is one of the numerous forms of HYDROMETER used in the arts. It consists of a hollow copper ball A, Fig. 111, with a flat brass stem *c d*, and a weight *a* of the same metal attached to the foot stalk *g h*; the weight *a* so adjusted that the instrument shall sink in distilled water at the temperature of 62° to the point *b* of the scale *c b*, which is divided into 10 equal parts. A barrel (36 gallons) of pure water at 62° weighs 360 lbs. avoirdupois, and the instrument is so regulated, that if put into a liquid weighing 361 lbs. per barrel, it would rise to the mark *e*. Each of the divisions between *e* and *b* will therefore represent tenths of a pound. A number of weights with holes in their centres, marked 1, 2, 3, 4, 5, 10, 20, and 30, accompany the instrument; these represent respectively pounds weight, and are placed as required on the top of the stem, and rest on the projection *d*. If, for example, in putting on the weight marked 10, the instrument sinks in a wort to the point *b*, a barrel of that wort at 62° would weigh exactly 10 lbs. more than a barrel of pure water. If the instrument cut the surface at two of the divisions below the point *b*, a barrel of the liquid would weigh 10.2 lbs. more than a barrel of water, or 370.2 lbs. But the brewer in speaking of his worts does not take into account the weight of the water; thus a barrel of wort weighing 370 lbs. is spoken of as a ten pound wort, and in this way all his calculations are made. The following are examples:—

Fig. 111.

Fig. 112.

	Barrels.		lbs. gravity.		
The 1st wort	12	at	35	=	420
2d „	14	at	20	=	280
3d „	14	at	6	=	84
	40	at	19.6 av.	=	784

or 40 barrels of wort, which, if mixed together, would average 19.6 lbs. per barrel. This would be too weak for ale, and too strong for small beer. Suppose the worts to be mixed in other proportions, such as,

	Barrels.		lbs. gravity.		
1st wort	12	at	35	=	420
2d „	7	at	20	=	140
Strong ale	19	at	29.4	=	560

There will therefore remain,

2d wort	7	at	20	=	140
3d „	14	at	6	=	84
Small beer	21	at	10.6	=	224

C, Fig. 112, is an assay jar, furnished with a cover B, and is used for containing the wort which is to be weighed by the saccharometer.

When the worts are graduated to the proper strength, they are pumped from the underback as quickly as possible into the copper, which is usually a close vessel with a valve at the top (Fig. 110), loaded so that steam cannot escape at the temperature of 212°. The temperature therefore rises a little above this, when a portion of steam by its increased elasticity forces open the valve and escapes, while the temperature of the wort falls back to 212°. In this way the liquor is concentrated by boiling, and also made clear by the coagulation of the albumen of the barley, which the brewers term *mucilage*. The glutinous matter is also rendered insoluble by combining with the tannin of the hops. As soon as the wort is introduced into the copper, the proper proportion of hops is added, and the two are boiled together until the mixture becomes clear. It is necessary to keep the hops well stirred up during the boiling, to prevent them from settling at the bottom and burning. For this purpose a vertical rod passes into the copper through a stuffing box at the top. This rod terminates in a horizontal bar, carrying an extended chain called a *rouser*, and both are kept in motion by being connected with the moving machinery of the brewery. To prevent the loss of the volatile oil of the hops, a copper pan of water is placed at the top of the boiler, so arranged that the tube which permits the escape of steam and oily vapour passes both into the water, where they are condensed. The water thus impregnated is used in the next mashing.

The quantity of hops depends on the quality of the beer, the time of keeping, the season at which it is brewed, and the climate to which it is to be exported. A larger proportion of hops should be used in brewing in warm than in cold weather, and also if the beer is to be kept a long time or sent to a warm climate. The Kent and Sussex hop is strong and pungent, and is hence preferred by porter brewers; the Worcester hop, being milder and paler, is used for ales. For strong beer, 4½ lbs. of hops to a quarter of malt is sometimes allowed. For the stronger kinds of ale and porter the rule is, in England, to allow 1 lb. of hops for every bushel of malt,

or 8 lbs. to the quarter; but for common beer, seldom more than $\frac{1}{4}$ lb. hops to the bushel is allowed.

The boiling being complete, all the bitterness of the hop being extracted, the worts are let down into the *hop-back*, which is a cistern with a metal bottom full of small holes, which acts as a strainer. The liquor is then passed into the *cooler*, Fig. 113, a shallow vessel of considerable area, usually situated at the top of the brewery, and exposed on all sides to a current of air. The cooling ought to be as rapid as possible, to prevent acetification, or, as the brewers term it, *foxing*, for which purpose a horizontal fan, moving rapidly round, creates a powerful draught of air over the surface. A rapid cooling is sometimes effected by passing the wort through long pipes, which are surrounded by large quantities of cold water: this expedites the business of the brewery, and greatly diminishes the risk of foxing.

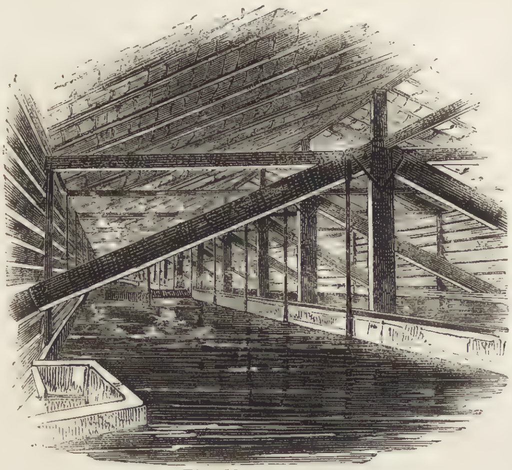


Fig. 113. THE COOLER.

When the worts are cooled down to 55° or 60°, and in some cases 63°, they are received into the fermenting tun, which is a vast circular vat or tub bound with strong iron hoops and covered in at all parts, except a hole which may be opened to inspect the process or to clean out the tun. A quantity of yeast is then added, varying with the strength of the wort and the season of the year; but in general, 1 gallon of yeast is sufficient to set 100 gallons of wort in complete fermentation. In warm weather the yeast is not added at once; but portions of the worts are let down from the coolers into the fermenting tun at different times, and a small portion of yeast is added each time. With large quantities of wort the temperature often rises very rapidly, and many precautions are required to prevent the fermentation from becoming unmanageable. For the scientific opinions respecting fermentation, we must refer to our article on that subject, but the phenomena of the process as it respects ale, are well described by Mr. Donovan:—"After the mixture of wort and yeast has been made some time, a frothy ring is observed leaving the sides of the tun, and proceeding a few inches towards the centre; and this is succeeded by another and another until at length the whole surface is covered with a thin creamy froth. At the same time a hissing noise, or feeble effervescence is heard, owing to the breaking of innumerable air bubbles on the surface; and there is a small increase of volume, occasioned by involved carbonic acid. Meanwhile the froth rises higher; at first equally, and at length into abrupt elevations resembling *rocks*, as they are called by brewers. The colour of the froth at this period deepens: at first it was white; next it became yellow; and lastly, (although it is better if not,) it often becomes a brownish yellow. The froth is now highest in the middle of the tun, and the fermentation is at its *maximum*. At this time the froth has become more viscid; it holds the carbonic acid more obstinately involved; the bubbles break into each other and form large ones, which in their turn break, and occasion sudden subsidence in different parts of the foamy head. At length the whole head begins to flatten and subside; the middle part, which was the highest, becoming now the lowest; and the fermentation diminishes. The viscid head of yeast becomes more dense; and having parted with its gas, would soon fall down to the bottom of the tun if permitted; but at that period it is skimmed off, and the skimming repeated at intervals, as fast as yeast appears on it. This is done as well to lessen the fermentation as to remove a certain disagreeable bitterness, with which this first yeast is impregnated, and which there is a risk of returning to the wort, were it not now removed." [1]

During this vinous fermentation, a portion of the sugar of the wort is converted into alcohol. When the active fermentation is over, the head formed on the liquor in the tun would, if left to itself, subside; the effervescence would entirely cease; the liquor would become transparent; but after a short time a new set of changes would take place; the acetous fermentation would set in, and the contents of the vat would be converted into vinegar. [See ACETIC ACID.] To prevent this, and at the same time to retain the alcohol, the aroma and bitter of the hop, and the carbonic acid in solution, and to cleanse the beer of the minute particles of yeast which are floating through it and rendering it muddy, the beer is racked off into a number of vessels like hogsheads called the *rounds* (Fig. 114), in which the vinous fermentation is completed. A large quantity of carbonic acid is slowly liberated, which, attaching itself to the suspended particles of yeast, carries them up to the bung-hole, where both are expelled. The bung-hole of each cask is furnished with a sloping tray, which discharges the yeast into a wooden trough, in which the stillions stand (Fig. 114). These stillions are placed in communication with a store tub, which keeps the rounds always full, so that the head of yeast may pass freely over, and keep the body of the liquor in the cask clean.

When the fermentation is over, the beer is either pumped up from the rounds into immense store-vats (Fig. 115), some of which contain upwards of 1,500

(1) Cabinet Cyclopædia. Domestic Economy, vol. i.

barrels, where it is kept until required to be drawn off into casks for consumption, or, in the case of ale, the cleansing is carried on in the casks in which the liquor is afterwards sent out. After the cleansing, the casks are bunged down tightly, so that the carbonic acid, which is still generated in small quantity, may be retained by mechanical pressure in the beverage, and

Fig. 114. CLEANSING VATS.

impart to it that sprightliness, sharpness, and foaming head, which are so much admired. It is important to arrest the fermentation while a good deal of saccharine matter remains in the beer, for if this were all expended, there would be nothing to prevent it from passing into the acetous fermentation. It is also of importance to carry the fermentation far enough;

Fig. 115. STORE VATS.

otherwise there will be too little carbonic acid generated; the beer will be mawkishly sweet and heavy, from a deficiency of alcohol; and it will be liable to *fretting*, or occasional bursts of weak fermentation, whenever the weather becomes warmer than usual.

The store cellars should be kept as cool as possible, free from alternations of temperature, vibrations of carriages, &c. The beer is never stationary in its quality, even in the store vats; for as soon as it ceases to improve by the decomposition of its residuary sugar, it begins to degenerate into vinegar. In common strong ale or beer, the proportion of alcohol is about 4 per cent.; in the best brown stout, 6; in the strongest ale, 8; but in common beer, not more than 1 per cent. The nutritive properties of beer depend on its gum, sugar, and starch-gum in solution. It also contains aromatic matters, lactic acid, different salts, and free carbonic acid, the latter varying from 2 to 25 or 26 per cent.

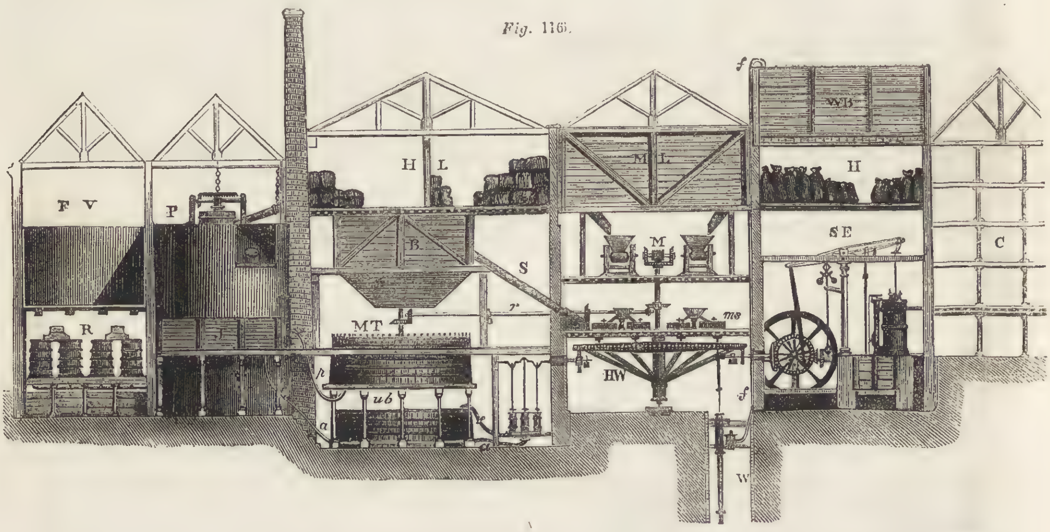
The cleansing is sometimes hastened by means of *fining:* that is, a solution of isinglass in weak sour beer, made from a fourth mash of the same malt, is put into every cask. It forms a kind of web over the surface of the liquor, and gradually sinking to the bottom, carries with it all the flocculent matter, and leaves the beer transparent.

We see, then, that by the process of fermentation the heavy wort has become transformed into a liquid now called beer or ale, of much less specific gravity, in consequence of the dense saccharine solution being partly transformed into a light spirit. This process of *attenuation*, as it is called (from *tenuis*, thin), is carefully watched by the brewer, and measured by the saccharometer, by which means he can judge of the quantity of alcohol formed, and compare it with the amount of sugar which the same instrument indicated to him as present in the worts; he can thus determine the amount of unaltered sugar yet remaining in the beer as its food, and thus judge of the time that it can be kept.

We will now, with the assistance of a diagram, briefly recapitulate the various processes of brewing on a large scale. Fig. 116 is the arrangement of a large porter brewery. The malt is hoisted up from the street by means of a crane, and is stored in spacious granaries or malt-lofts, M L, at the top of the building. Immediately below the granary is the mill M, for crushing the malt, and in the floor below are mill-stones, *m s*, for grinding the malt, when it is required to do so. The crushed or ground malt is conveyed by a trough into a chest, *c*, from which it is raised by the action of a spiral screw into the large chest or bin, B, situated directly over the mash-tun, M T, into which it is let down as it is wanted. The water for the service of the brewery is obtained from the well W by a lifting-pump, worked by the steam-engine S E; a forcing-pipe *f* of the pump conveys water up to the large cistern or water-back, W B, at the top of the engine-house. From this cistern iron pipes are laid to the copper P, and also to every part of the brewery where water is wanted for cleansing and washing the vessels. The copper P can be filled by turning a cock, and the water, when heated, is conveyed by the pipe *p* into the mash-tun M T. It is introduced beneath a perforated false bottom, upon which the malt lies, and, rising up through the holes, comes in contact with the malt. The copper is immediately refilled for a second mash. The wort from the malt is drained off into an underback, *u b*, situated

immediately under the mash-tun, from which it is pumped into the copper P, or into a vessel situated above it, by means of the three-barrelled pump along a tube not shown in the diagram. When the water for the succeeding mashes is let out of the copper, the wort is introduced, with the proper proportion of hops, from the hop-loft H. When the boiling has continued a sufficient length of time, the contents of the copper are run off through a large cock into the jack-back, J, which has a perforated bottom to strain off the hops. The hot wort is drawn off from the jack-back through the pipe *a* by the three-barrelled pump, which throws it up into the coolers, C, which are built in several stages, and open at the side, by means of louvers, to the air. When the wort is sufficiently cooled, it is conducted in pipes from all the different coolers to the large fermenting-vessel, F V, in which the first fermentation is conducted. From this vessel the beer is introduced into the rounds, R, where the fermentation is completed, after which the beer is drawn off into immense store vats, where it is kept till wanted. The steam-engine, S E, which gives motion to the machinery, has attached to its large fly-wheel a bevelled cog-wheel, which turns another similar wheel upon the end of a horizontal shaft which extends from the engine-house to the great horse-wheel, H W, which it turns by means of a cog-wheel. The horse-wheel puts in motion all the pinions for the mill-stones and rollers, the horizontal axis which works the three-barrelled pump, and the machinery within the mash-tun for agitating the malt. It also moves a sack-tackle for drawing up the sacks of malt and hops from the court-yard to the top of the building. The hops are kept in their bags and pockets, but the malt is emptied out of the sacks into enormous bins. The horse-wheel, H W, can be worked by horses, should the steam-engine fail, which, however, is a rare occurrence.

Fig. 116.



In one of the breweries visited by the writer and Mr. W. H. Prior, who made the drawings for the engravings which illustrate this article, the quantity of malt wetted during the winter brewing season every Tuesday and Friday is 320 quarters, and on the four other days of the week 230 quarters. There were three coppers of the capacities of 350, 500, and 600 barrels. The coal consumed per day is 10 or 12 tons, and the capacity of the largest store vat is equal to 1,568 barrels.

We have thus indicated the general processes of brewing as they are conducted in a London brewery. They are the same in principle wherever they are carried on. There are, however, variations in practice or in the quality of the materials, in different districts, which afford characteristic differences in the product. The Scotch ale is justly celebrated for its mild flavour and pale colour, more resembling the pale wines of France than any other ales that are brewed in Great Britain, and, like them, it is the result of a lengthened fermentation. The low heat at which the tun is pitched confines the brewing to the colder part of the year, all operations being suspended in the summer months. The Edinburgh brewer is particularly careful in the choice of his malt, and hops, and yeast. He only makes one mash for strong ale, and completes his quantity or *length* of wort by eight or ten subsequent sprinklings or *sparges* of liquor over the goods. These sparges trickle in succession through the malt, and wash out as much more of the saccharine from the mash as may suffice for the intended strength of the ale. The mashing is begun with water at 180° or even 190°, and after working up the malt for half an hour, the whole is covered up, and allowed to infuse about three hours, when it is drained off into the underback. Water at 180° is then sprinkled equally over the goods by being poured upon a circular board swung over the centre of the mash-tun, and, being perforated with small holes, the water descends in a shower. Three or four stop-cocks are inserted in different parts of the bottom of the tun, for drawing off the liquor, in order that it may permeate every part of the goods equally. When the first sparge is run off, which may be in 20 or 25 minutes, a second

sparge is showered in; after this a third, and so on, until the length is made up of the proper specific gravity.

The quantity of hops seldom exceeds 4lbs. to the quarter of malt. A little honey and a few coriander seeds, or other aromatics, will assist the flavour. After the boiling, the worts are cooled down as low as 50°, and even 45°. The fermentation is carried on for a fortnight or three weeks. As small a portion of yeast is used as possible, and this is sometimes added in two separate portions; and, to prevent the fermentation from becoming slack, the tun is stirred up or roused twice a day, morning and evening, if necessary. When the fermentation has slackened, the ale is cleansed, or the top barm might re-enter the body of the liquor, and it would become *yeast-bitten*. When the ale is cleansed, the head, which has not been disturbed for some days, is allowed to float on the surface till the whole of the then pure ale is drawn off into casks. After this cleansing there is little or no yeast given off, as nearly the whole of the fermentation has been completed in the tun. The strength of the best Scotch ale varies from 32 to 44 lbs. to the barrel. The ale soon becomes fine, and is seldom racked for the home market.[1]

Among the multitude of recipes for domestic brewing, on a small scale, one of the best (we speak from the experience of several years) is that given by Mr. Donovan, in the work already quoted. The great objection to domestic brewing is often the expense of the apparatus; but this writer shows how cheaply this may be procured. A common porter-barrel forms the mash-tun, for which purpose one end is to be taken out, and converted into a false bottom by letting it rest on a hoop nailed round the lower part of the barrel. This false bottom is to be perforated with a vast number of gimlet-holes, and a cock or spigot of wood is to be fixed in one of the staves, between the real and the false bottom. Another porter-barrel, with one end taken out, will serve both as underback and fermenting-tun, and it may be placed beneath the cock of the mash-tun, so as to receive the wort when it is drawn off. A tin-plate boiler, furnished with a cock at the bottom, for placing over a common fire-grate, is recommended for heating the mash liquors; but we prefer to use the laundry copper, which is provided in every house. A brewing thermometer may be used, but can be dispensed with, as the proper heats can be determined by the admixture of cold and boiling water.

15 gallons of boiling water are to be thrown into the mash-tun, and 5 of cold water (60°). The temperature of the mixture would be 174°, but for the cooling influence of the wooden vessel, which, however, should be well scalded immediately before. The mash-water will be about 170°. $2\frac{1}{2}$ bushels of the best ground pale malt are to be quickly shaken in, while a second person continually stirs with a stick, and this mashing is to be continued for half an hour, the barrel being covered over all the time with a thick cloth, except in the small space where the stick is inserted. The tun should then be left quiet for an hour, after which the cock may be opened a little. The first flow of wort should be received into a wooden bowl: if not clear, it should be gently poured back into the mash-tun; but as soon as it begins to flow clear, the cock may be opened to the full. The malt will have soaked up the greater portion of the water, but the few gallons which flow off ought to be a full, rich, clear wort. Just when the last portions have run off, 20 gallons of water, not quite boiling, are to be lightly let over the residual grains. The wort retained by the malt will thus be washed down, and the whole quantity now in the underback will amount to 23 gallons. This is to be baled into the copper, and boiled for 20 minutes with $3\frac{1}{4}$lbs of the best mild hops, after which it is to be passed through a large sieve into the fermenting-tun; and when it has cooled nearly to blood-heat (98°), about a quart of good yeast is to be mixed in, and the fermentation is to be continued until completed. In cold weather the tun while working must be kept near the fire, as on this small scale the wort does not maintain the temperature adapted for working. When the fermentation shows a decided tendency to go down, the liquor is to be racked off, and put into a cask, and closely bunged up. The ale will measure 20 gallons, and will be ready for use in about a fortnight.

(1) Booth: "Treatise on Brewing," in the Library of Useful Knowledge.

BEET, BETA. This important plant belongs to the natural order Chenopodiaceæ, which also includes Spinach, Orach, Mercury, Goose-foot, &c. Beet, more commonly known by its German name of *mangold wurzel*, is now famous as affording a new source of sugar, capable of being produced in northern countries. Common Beet (*Beta vulgaris*) has been extensively and successfully cultivated for this manufacture, which was commenced in the time of Napoleon, to gratify his earnest desire of rendering France independent of England, and was carried on under his constant notice and patronage, so that it is said he proudly exhibited the first specimen of beet-root sugar as one of his greatest treasures. The mode of cultivation recommended by French naturalists, and found successful in rearing the plants, was as follows:—A low situation should be chosen, in which extremes of drought and moisture do not occur. The soil (which should be a rich loam in which wheat has been grown,) must have three good ploughings, and immediately after the third, which should take place at the end of April or beginning of May, it must be brought smooth by the harrow, and laid out for planting. This is done in France by means of a rake, whose teeth are from 9 to 12 inches apart, and are therefore fitted to make lines along the surface, showing the distance each row of plants is to be from the other. The rake is afterwards drawn in transverse lines across these, and the ground divided into squares, measured by the distance of the rake's teeth. Into each intersecting point of these lines, one capsule containing several seeds is inserted to the depth of an inch. When the young plants begin to spring up, and six or eight leaves are

formed, the ground should be weeded, and if necessary, the plants thinned. After this the crop advances so rapidly that the outspreading leaves soon cover the ground, and thus completely prevent the growth of any more weeds. There is therefore no more trouble with the ground till the time of gathering, an important circumstance for the cultivator, who is then busy with his corn harvest. The beet does not attain its full perfection till the month of October.

The best seed is that obtained from beet which has not been transplanted, and which has produced thin spindle-formed roots. Among the varieties which produce this kind of root, one has a pale red rind, and is internally quite white. This is a valuable variety to the manufacturer, yielding much sugar and an agreeably sweet syrup; others have a deeper red rind, and reddish circles or stripes within. These have a less agreeable syrup, retaining a taste of the root, which cannot be removed without expensive chemical processes. Other varieties are white on the outside and yellow within. These yield much crystallizable sugar, but are not fit for moist or raw sugar on account of the disagreeable taste of the syrup.

Various experiments have been tried with beet, to ascertain the effect of light on the development of the saccharine principle, and it seems to be fully proved that as in the case of asparagus, endive, &c., the part protected from the light becomes sweet, while the other parts remain bitter, so with beet-root, the saccharine principle is greatest in those roots which are the most effectually protected from the light. Thus the natural growth of these plants, by which the leaves form a thick and umbrageous covering to the whole of the ground, should by no means be interfered with, and the practice occasionally followed of removing all the large leaves, is one which must necessarily deprive the root of a portion of its most valuable properties. The only leaves which it is safe to remove are those which have begun to droop or decay; but to pluck the large succulent leaves, however convenient they may be as food for cattle, is very unwise in those who grow beet for making sugar. For a description of the process by which the sugar is obtained from beet-root, see SUGAR.

BELL. [See CASTING.]

BELL-METAL. An alloy of copper and tin. [See BRONZE. CASTING.]

BELLOWS and BLOWING MACHINES. The common bellows is a very ancient instrument for assisting the combustion of a fire, by injecting into it a larger portion of air than would be supplied without such aid. The first form of this machine resembles that of the lungs, and was doubtless suggested by the common practice of blowing the fire by means of the mouth. It consists of two flat boards of an oval or triangular shape, each furnished with a projecting handle, and between the boards two or more hoops are bent to suit their figure. To the edges of the boards is nailed a piece of leather, broad in the middle, so as partly to enfold the hoops, and narrow at the two ends, thus forming a sort of enclosed chamber, capable of being enlarged or contracted by raising the upper board while the lower one remains stationary. To the lower board is fastened a metal pipe, and a hole is also made in the centre of this board, which is covered on the inside with a leathern flap or valve opening inwards. On raising the upper board the enclosed air is of course rarefied, and air from without rushes in by lifting up the valve. Then on pressing down the top board, the air is compressed, and driven forward along the pipe with a velocity depending on the amount of force with which the two boards are pressed together. The blast is not continuous, but in puffs,[1] an interval of time being required for the air to enter the bellows through the valve, the blowing interval being to the filling interval as the areas of the apertures. In the oldest smelting houses this irregular blast was remedied by employing two bellows which blew alternately, the one blowing while the other was filling. To supersede the necessity of frequent repairs, they were made entirely of wood, except the pipe or twyere. This invention is ascribed by Beckmann to one Lewis Pfannenschmid, of Thuringia, who settled at Ostfeld, near Goslar, in 1621, where he excited the jealousy of the bellows-makers of the place by the superiority of his machines. It is stated, however, that bellows entirely of wood for smelting houses and for organs, were constructed at Nuremberg as early as 1550. Beckmann describes these machines in the following terms:—"The whole machine consists of two boxes placed the one upon the other, the uppermost of which can be moved up and down upon the lower one, in the same manner as the lid of a snuff box which has a hinge moves up and down when it is opened or shut, but the sides of the uppermost box are so broad as to contain the lowermost one between them, when it is raised to its utmost extent. Both boxes are bound together at the smallest end where the pipe is, by a strong iron bolt. It may be readily comprehended, that when both boxes fit each other exactly, and the upper one is raised over the under one, which is in a state of rest, the space contained by both will be increased; and consequently more air will rush in through the valve in the bottom of the lower one; and when the upper box is again forced down, this air will be expelled through the pipe. The only difficulty is to prevent the air which forces its way in from escaping anywhere else than through the pipe; for it is not to be expected that the boxes will fit each other so closely as to prevent entirely the air from making its way between them. This difficulty, however, is obviated by the following simple and ingenious method:—On the inner sides of the uppermost box

(1) A very convenient form of domestic bellows was introduced a few years ago, producing a constant blast. A vaned wheel was enclosed in a tinned-iron box communicating with a tube. The supply of air was obtained by means of holes in the side of the vessel, so that by turning a small multiplying wheel at the side, the vane was set spinning, and, drawing the air in, projected it out along the tube.

there are placed movable slips of wood, which by means of metal springs are pressed to the sides of the other box, and fill up the space between them. As these long slips of wood might not be sufficiently pliable to suffer themselves to be pressed close enough, and as, though planed perfectly straight at first, they would in time become warped in various directions, incisions are made in them across through their whole length, at the distance of from 15 to 18 inches from each other, so as to leave only a small space in their thickness, by which means they acquire sufficient pliability to be everywhere pressed close enough to the sides." These bellows are made of clean fir-wood without knots. They are represented in Fig. 117, in which A E B F is the upper chest. B F the line of hinges, H the handle, and P the blast pipe,

Fig. 117.

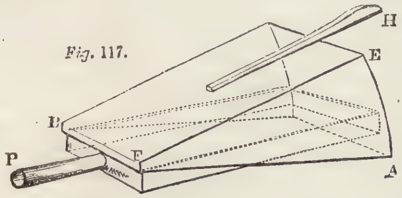
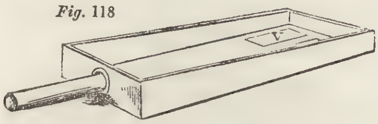


Fig. 118



which is sometimes furnished with a valve opening outwards, to prevent the burning coals from being sucked into the bellows when the upper box is drawn up. The lower box, with one of the valves V, is shown separately in Fig. 118. The slips of wood at the sides are apt to become damaged, but they can be easily repaired, and every 3 or 4 months the outer sides of the inner box and the bolt which keeps the boxes together must be smeared with oil.

These bellows are of very large size; they are 16 feet long by 5 feet, and the circular end is also 5 feet. The rise is 3 or $3\frac{1}{2}$ feet, expelling at each stroke about 90 cubic feet of air, and making eight strokes per minute.

The great objection to bellows of this kind, is the want of a continuous blast. This was first remedied by the addition to the single bellows first described, of a third board of the same shape as the other two, and connected with the lower board by means of a piece of leather, thus making two exactly similar cavities or chambers, separated by the lower board of the single bellows, which now becomes the middle board of the double bellows. Each of these two boards is furnished with a valve, and the blast-pipe is connected with the upper part of the middle board. The lower board is held down by a weight, and a weight is also placed on the top board, by which means the air is forced out of the upper cavity through the pipe. In blowing, the middle board is raised, by which means air rushes into the lower cavity, and in its descent forces air into the upper cavity, the valves preventing its return, and the weight on the upper board forces it out through the pipe in a continuous blast. Thus it will be seen, that the ascent of the middle board fills the lower cavity while the descent fills the upper cavity, and the weight of the top board drives the air out in a blast; thus the irregular puffing action of the single bellows is here confined to the lower board, which supplies air to the upper cavity. The blast, although continuous, is not, however, quite regular, for when the air is forced into the upper cavity, an excess of pressure is communicated to the air contained therein, but this is of no consequence in a smith's forge.

This construction will be understood by reference to the bellows in Halley's portable forge, Fig. 119, in which *a a* is a square frame of iron passing round the whole; *b b*, pillars supporting the platform or hearth for the forge fire; *d*, the bellows made fast by the middle flap to the frame *a*, and worked by the handle *e*, inserted in a socket at the top of the lever *f*; this lever and a corresponding arm on the opposite side, swinging upon pivots mounted on the sides of the frame *a*, and connected by a rod *g*, which passes across the machine under the bellows. By depressing the handle *e*, the levers *f* lift the rods and the bottom flap of the bellows, and on lowering the handle this flap falls by its own weight, thus producing the blast for working the forge. The flaps are covered with iron plates to increase the effect, and are nearly square to afford greater space. The collapsing of the upper flap forces the blast up the pipe *h* to the fire. To make this furnace portable, the parts are taken asunder, and the bellows and frame are placed on the hearth *c*, the pipe *h* and the legs *b* are packed on the top and sides of the bellows, and the whole is shut up in a box, formed by the hearth of the forge with its side plates; the cover is then turned down by its hinge-joints upon the box, and secured by a hasp and padlock.

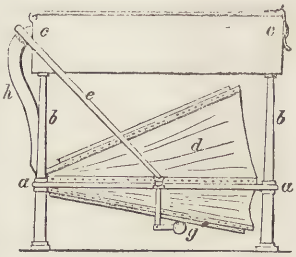


Fig. 119.

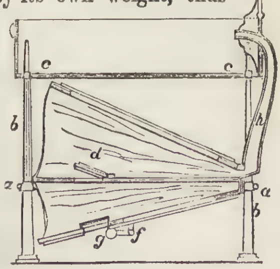
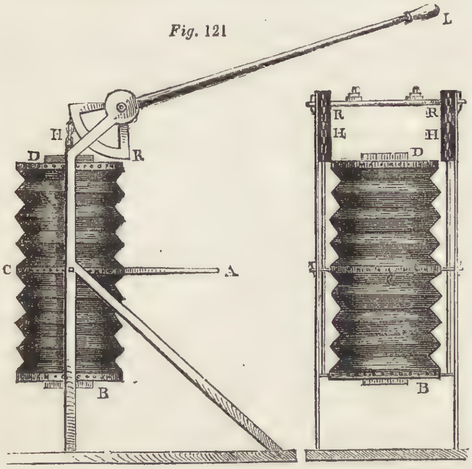


Fig. 120.

The smith's bellows is worked by means of a rocker, with a string or chain fastened to it. By drawing down the handle of the rocker the movable board rises. The smith's bellows is sometimes made circular, the boards being in a horizontal position, parallel to each other, as in Fig. 121, in which A is the blast-pipe, B the movable lower board, C the fixed board with the pipe inserted, D the upper moveable board loaded with a weight. Motion is given

to the lower board by means of a lever L, and a chain H working on a roller R. The weight required to produce a certain force of blast is easily determined, for if the diameter of the bellows be 1 foot the area

Fig. 121



will be 113.19 inches, and the upper board would require a weight of 56.5 lbs. for a blast equivalent to a pressure of $\frac{1}{2}$ lb. on the square inch, or a velocity of 207 feet per second, a blast well adapted to a smith's forge. The force of the blast can be varied by altering the diameter of the pipe, for which a special contrivance is sometimes made. In portable forges, the boards are brought together by means of helical springs instead of weights.

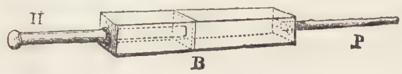
In some of the native furnaces for smelting iron ore in Hindostan two bellows made of skin are used; a pipe projects from the bottom of each, and is

Fig. 122. INDIAN BELLOWS.

united with the blast-pipes of the twyere. These bellows are placed on a plank laid across a trench in front of the furnace, and at the further end of the plank is seated a man, who by working the bellows alternately, one with the right, and the other with the left hand, produces a continuous blast. In front of the furnace is an ingenious contrivance for preventing the twyere from rising when the bellows is drawn up. It consists of a bar, the bottom of which presses on the end of the twyere, while its tip hitches into a loop of iron placed between two laternal studs or staples. The dotted line shows the form of the hearth, and the direction of the flue.

A very simple form of bellows, perhaps the simplest, is that used by the Chinese smiths. It consists of a square pipe of wood, Fig. 123, with a square board B exactly fitting it, which is moved to

Fig. 123.



and fro by means of a handle H. At the further end is the blast-pipe P, and in each side is a valve (shown by the dotted line) opening inwards.

A very ingenious and powerful blowing machine, founded on the principle of the Chinese bellows, was constructed some years ago by Mr. Vaughan, and is described in the Encyclopædia Britannica. It consists of two square boxes placed side by side. A piston, P P′, Fig. 124, fitting each, is

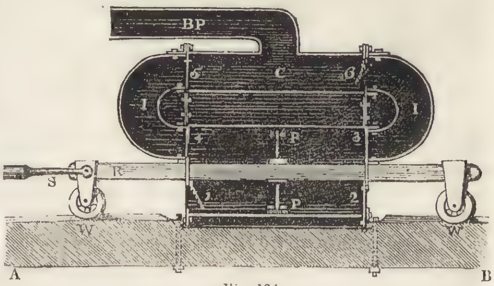
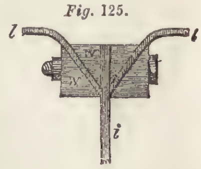


Fig 124.

drawn backwards and forwards by means of the rod R, working horizontally on wheels W W, by means of the spear S, which communicates with the crank of a wheel at some distance off. The body of the piston is a cast-iron plate with a socket in the middle to receive the rod; the diameter of the piston is about $\frac{1}{4}$ of an inch less than that of the box, and it is made tight by the following ingenious arrangement. Two pieces of wood, W, are cut diagonally to receive pieces of leather, *l l*, between them, and both the leather and the wood are firmly bolted to the plate of the piston *i*. The leathers extend about two inches beyond the wood, and their slight elasticity keeps them in contact

Fig. 125.



with the metallic surface, so that when the piston is in motion the leather on one side claps close to the surface, rendering it air-tight, while the leather on the other side is loose.

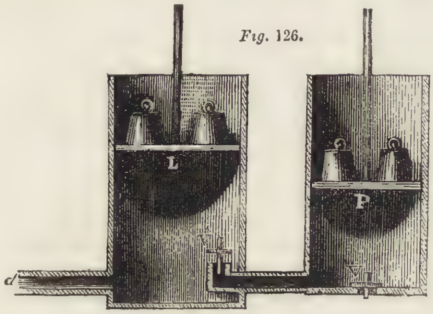
The projecting curved pipes, I I′, communicate between the box where the piston works and the air-chest C. When the piston moves from A to B, the valves 1, 3 open, while 2, 4 remain shut. The air contained in the box is forced through the valve 6,

into the chest C, and thence along the blast-pipe B P. In the return stroke, which is the whole length of the box, the valves 1, 3 are shut, while 2, 4 are open, and the air is forced through 5 and then along B P.

Two of these machines work at the same time by two cranks, so that one is in full blast while the other is returning the stroke; hence there are 4 puffs produced by 2 double strokes, and these occurring alternately at almost equal intervals, a steady blast is produced. Mr. Vaughan recommends that four of these boxes be at work at once, so as to produce 8 puffs in one double stroke, which if divided by equal intervals, produce a sufficiently uniform blast for any purpose. The machine makes 70 strokes per minute; the nose-pipe, where the blast enters the furnace, is $2\frac{1}{2}$ inches in diameter, and discharges 1,200 cubic feet per minute.

A uniform blast is also produced by the arrangement shown in Fig. 126, in which two cylinders are

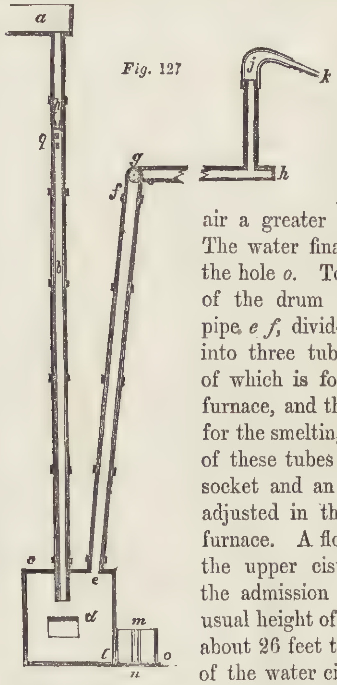
Fig. 126.



connected with each other and with the discharge pipe. P is the working piston, which is worked by a rod connected by double chains with the arched head of a working beam moving round a gudgeon. By the descent of this piston, the air is compressed and forced through the valve V, while the loaded piston L is raised to its highest point. The piston P now ascends, and its cylinder is filled with air through the valve V′, during which time the loaded piston gradually descends. The valve V is closed by the pressure and the air is forced out through the discharge pipe *d*. Before all the air in the cylinder L is discharged, it receives a fresh supply by the descent of P, and thus while the engine is in motion the blast is rendered continuous.

The *trompe*, or water-blowing engine, Fig. 127, is an ingenious and economical method of obtaining a blast. It is used in Savoy, Carniola, and in America. It is formed of two pipes or funnels, one of which is at *b*, set upright, and terminating above in a cistern of water *a*, and below is a tub or drum *c*. The conical part *p*, just below the cistern, is called the *etranguillon*, and prevents the water discharged into the trompe from filling the pipe in falling, but divides it into many streamlets. Below this narrow part a number of holes *q q* are perforated obliquely, through which air is admitted and carried by the water in its descent. The air parts with the water by dashing upon a cast-iron slab *d* within the drum. At the bottom of the drum is an aperture ˜ for the escape of the water, but to prevent the air from escaping with it, the water as it issues is received into a chest *l m n o*, divided into two parts by a vertical slide-plate between *m n*. By raising or lowering this plate the water may be maintained at any required level within the drum, so as to give the included air a greater or less pressure. The water finally drains off by the hole *o*. To the upper part of the drum is fitted the air pipe *e f*, divided at the point *f* into three tubes, the principal of which is for the cupellation furnace, and the other two at *g* for the smelting furnaces. Each of these tubes ends in a leather socket and an iron nose-pipe *k* adjusted in the twyere of the furnace. A flood-gate fitted in the upper cistern *a* regulates the admission of water. The usual height of this apparatus is about 26 feet to the upper level of the water cistern. Its total length is $36\frac{1}{2}$ feet, and its width 2 feet to give room for the drums.

Fig. 127



One of the most powerful and perfect blowing machines in the kingdom is that at Woolwich dockyard, which is used for supplying air to forty forge fires, amongst which are several fires for forging

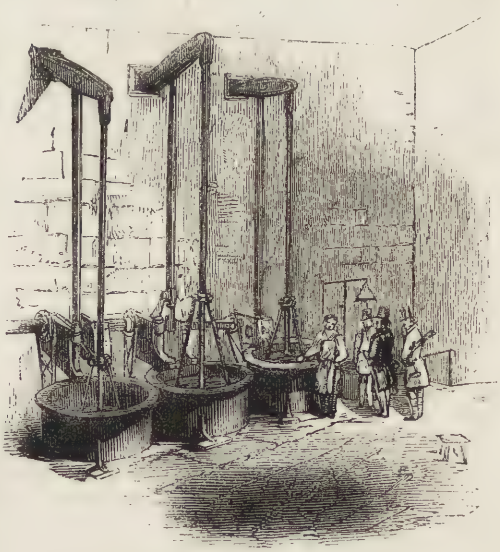


Fig. 128. THE WOOLWICH BLOWING MACHINE

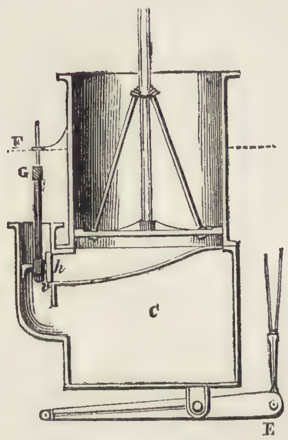
anchors, iron knees, and other heavy pieces of smithery. It consists of three blowing cylinders, Fig. 128, which are 5 feet 5 inches in length, of which 2 feet 4 inches is above the floor. The interior diameter of each cylinder is 4 feet 8 inches, which is

also the length of the stroke. Twenty strokes per minute are made in each of the three cylinders, corresponding to an expulsion of nearly 5,000 cubic feet of air per minute. The fourth cylinder is used to regulate the pressure, as will be explained presently.

The piston-rods are worked so that while one is at the highest, another is half-way down or up, and the third is quite down. A large iron wind-chest, 22 feet 5 inches long, is situated in the cellar below: on this the four cylinders are fixed. The bottom of the fourth cylinder is open to the chest; the others are closed at bottom. From this chest, under the third cylinder, proceeds the main eduction-pipe, from which branch-pipes proceed to the several forges, each pipe being furnished with a cock for turning the blast on or off. Behind the eduction-pipe is a short cylinder, containing a valve, shown in the section, Fig. 129, which passes through the axis both of the valve cylinder and the blowing cylinder.

On the principal axis are three eccentric wheels, with iron straps, connected with a lever under the wind-chest, and these wheels are so arranged in respect to the corresponding crank that when the piston of any cylinder is either above or below, the lever is horizontal, and the valve *v* exactly closes the hole *h*. When the piston in this figure begins to ascend, the end E of the lever continues to ascend also, and the other end F descends, and being connected with the valve-rod at G, this also descends, and opens a communication between the interior of the cylinder and the external air, which rushes in with a fresh supply. This valve continues to descend until the piston is half-way up; it then begins to ascend until the piston is at the highest point, when the valve has the position shown in the figure. The piston now descends, but the valve-rod continues to ascend, and opens a communication between the cylinder and the wind-chest, into which the air is forced by the piston. When the piston is half-way down, the valve-rod has reached the highest point, and then continues to descend with the piston until the latter is down, when the hole *h* is again covered with the valve. In this way the three cylinders are successively opened to the atmosphere and to the wind-chest, and a constant influx of air is produced. To preserve a steady action in the valve-rods, they are made to pass through guards level with the floor F. The fourth cylinder has no bottom, but is open to the wind-chest, and its piston, which weighs 700 lbs., serves only to regulate the pressure, which amounts to about $\frac{1}{4}$ lb. on the square inch. When the pressure exceeds this, the piston rises, and opens a safety-valve at the back of the cylinder. The form of the bottom of the cylinder in the section belongs only to that part of the cylinder: the other part is perfectly flat, its purpose being to open a communication with the valve-cylinder.

Fig. 129.

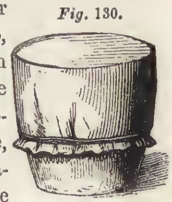


BENZOIC ACID. When bitter almonds are subjected to great pressure, a fixed oil is obtained. By distilling with water the almond-paste which remains, a volatile oil is obtained, which is prepared in large quantities, chiefly for the use of the perfumer. This oil does not pre-exist in the almonds, but appears to be formed by the action of water upon a peculiar crystallizable substance called *amygdaline*, aided by the presence of the pulpy albuminous matter of the seed. The crude oil has a yellow colour, and contains a quantity of hydrochloric acid, which is formed at the same time as the oil. By agitating it with a solution of protochloride of iron, containing an excess of hydrate of lime, and then distilling the whole, the essential oil is obtained in a purified form. It is freed from the water which passes over with it by means of fused chloride of calcium.

This oil is supposed to be the hydruret of a basic substance named *benzoyle*, from its relation to benzoic acid, containing $C_{14}\,H_5\,O_2$. Pure hydruret of benzoyle, or bitter-almond oil ($C_{14}\,H_5\,O_2 + H$), is a thin colourless fluid, of great refractive power, and of a peculiar and agreeable odour; its density is 1.043, and its boiling-point 356°. Its vapour is inflammable, and burns with a bright smoky flame. It is soluble in about 30 parts of water, but alcohol and ether dissolve it indefinitely. It absorbs oxygen rapidly from the air, and forms a mass of crystallized benzoic acid. It is doubtful whether the pure oil is poisonous, but the crude product is highly so, and yet this is sold for flavouring puddings, custards, &c.

Benzoic acid, or oxide of benzoyle, BzO ($C_{14}\,H_5\,O_2 + O$), is not usually obtained by the oxidation of bitter-almond oil. Several of the balsams, especially gum-benzoin, yield benzoic acid in abundance. By exposing this substance to a gentle heat in a subliming vessel, the benzoic acid is volatilized, and condensed in the upper part of the apparatus. The best contrivance for this purpose is a shallow iron pan, containing the substance to be sublimed, in a thin layer: a sheet of bibulous paper, pierced with a number of pin-holes, is stretched over the pan, and a cap of stout cartridge-paper, secured by a string or hoop, is drawn over the whole, as in Fig. 130. The pan is slowly heated on a sand-bath; the vapour of the acid condenses in the cap, and the crystals are prevented from falling back into the pan by the porous paper. The acid thus obtained is in the form of snow-white, light, feathery crystals, with a fragrant odour, which is due to the presence of a small quantity of volatile oil. A more abundant product may be obtained by mixing the powdered gum-benzoin with an equal weight of hydrate of lime, boiling the mixture with water, filtering, and evaporating, and then decomposing it with an excess

Fig. 130.



of hydrochloric acid. The benzoic acid crystallizes out on cooling, in thin plates, which may be drained upon a cloth filter, and dried in the air. By sublimation the acid may be obtained perfectly white. The crystals obtained in this way contain an equivalent of water, so that the formula for the hydrous acid is $C_{14}\, H_5\, O_3 + H\,O$.

Benzoic acid is inodorous when cold, but has a faint smell when gently heated; it fuses just below 212°, and sublimes a little above that point: it boils at 462°, and emits a dense vapour, which is very irritating to the throat and eyes. It dissolves in about 200 parts of cold, and 25 of boiling water. It dissolves in about twice its weight of alcohol; it also dissolves in ether, and in fat and volatile oils. It combines with bases, and forms salts, which are called *benzoates*.

Benzoic acid is an ingredient in some kinds of perfumery, and in fumigating powders and pastiles. It was formerly used as an expectorant in asthma and dry cough. When taken internally, it is rejected from the system in the state of hippuric acid, which occurs in large quantity, in combination with potash or soda, in the urine of horses, cows, and other graminivorous animals. If the urine be slightly putrid, it yields benzoic instead of hippuric acid. Much of the cheap benzoic acid of commerce is prepared in this way, the perfume being superadded by subliming with a little gum-benzoin. Benzoic acid is a principal ingredient in *friars'-balsam*, useful for stimulating languid wounds, but mischievous when applied to recent wounds. A cosmetic, under the name of *virgin's-milk*, is prepared by mixing two drachms of the alcoholic solution of benzoin with a pint of rose-water.

The other benzoyle compounds, such as the chloride, bromide, iodide, and sulphuret of benzoyle, possess great chemical interest, but are not of importance in a manufacturing point of view.

BILE. A secretion separated from venous blood by the largest internal organ of the body, the liver. It was regarded by the old chemists as a saponaceous compound, in which an organic acid was combined with soda. Modern chemists have re-adopted this view, regarding bile as a *soda-soap*, and, as such, the bile of the ox, or *ox-gall*, as it is called, is used in the arts, by painters in water-colours, scourers of clothes, and many others; but, from its green colour, it requires for many purposes to be clarified. This is done by allowing the fresh gall to settle for a day in a basin; the liquor is then poured off from the sediment into an evaporating-dish, and exposed to a boiling heat in a water-bath until it is somewhat thick. It is then spread upon a dish, and dried before the fire, in which state it may be kept for years in jelly-pots covered with paper. When required for use, a piece of the size of a pea may be dissolved in a table-spoonful of water. The gall may be made perfectly colourless by the following process: A pint of gall is to be boiled and skimmed, and an ounce of alum, in fine powder, or an ounce of common salt, added; the mixture to be kept on the fire until the alum is dissolved. The mixture, when cool, is to be poured into a bottle, and loosely corked. In about three months it deposits a thick sediment, and becomes clearer. The clearer portion of the gall prepared with alum is then to be mixed with the clear portion of the gall prepared with salt, when the colouring matter will be coagulated and precipitated, leaving the ox-gall perfectly colourless. It may, if necessary, be further purified by passing it through filtering-paper. This gall becomes purer by keeping, and never loses its good qualities, nor contracts a disagreeable smell.

Prepared gall combines with colouring matters and pigments, and gives them solidity either by being mixed with or passed over them upon paper. It adds to the brilliancy of ultramarine, carmine, green, and most delicate colours, and makes them spread more evenly upon paper, ivory, &c. Mixed with gum arabic, it thickens the colours without giving a glistening appearance; it prevents the gum from craking, and fixes the colours so well, that others may be applied over them without running into them. Mixed with lamp-black and gum, it forms a good imitation of China ink. A coat of ox-gall upon black-lead or crayon drawings prevents the lines from being effaced, and such drawings may be safely coloured by first mixing the colours with ox-gall. Miniature painters use it for removing the unctuous matter from the surface of ivory, and when ground with the colours it enables them to be spread easily and renders them fast. It is also useful for transparencies, by passing it first over the varnished or oiled paper and allowing it to dry. The colour is mixed with the gall and then applied, and cannot afterwards be removed.

It takes out spots of grease and oil, and is useful to the laundress in washing dresses, the colours of which would run or be removed by the ordinary process of washing. A small portion dropped into ink renders it fluid.

BINNACLE, or BITTACLE (from the French, *habitacle*, a small habitation). The box in which the compass is placed for steering a ship. The form is not of much importance by day, provided the man at the helm can get a good view of the compass-card; but at night it is of great consequence to throw the strong light of a lamp on the card, to preserve the lamp from the action of wind and weather, and to prevent its light from being seen out of the ship.

Sir Home Popham's binnacle is in general use in the navy. It consists of a square box about 2 feet high and 18 inches in the side, with a top in the form of the frustum of a square pyramid. The four sides are glazed with plate-glass, and the compass-card, which is about level with the upper part of the square box, is distinctly seen. By night thin copper screens shut up those sides which are not necessary for the steersman's purpose, and the inner surfaces of these screens assist in reflecting the light of the lamp strongly upon the card. The lamp is attached to one of these screens, a hole being cut in it to admit the necessary light. To prevent the fracture of the glass

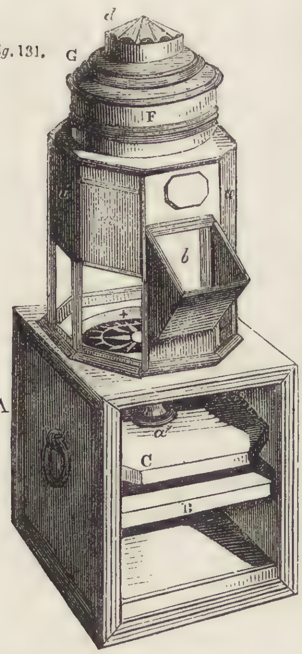
surfaces, the four edges of the frustum are defended by a strong wooden frame with projecting edges, and at the top by a flat piece of wood also projecting considerably beyond the glass.

A good arrangement of a ship's binnacle is that by Mr. Grant Preston, of Wapping, described in the Transactions of the Society of Arts. The defects of the ordinary binnacle and compass-box are first pointed out by him. The compass-box is generally of wood, and square, containing within it a circular brass box suspended on gimbals; within this is the compass-card, the points of which are read against a mark within the brass box, called the *lubber's point* or *mark*. A line drawn from this to the centre of the compass-card should be exactly parallel to the line of the ship's keel, or her course by the compass will not be correct. The mode of fitting the compass-box into the binnacle is by driving wedges all round to make it fast, but nothing is done to make it truly parallel with the ship's keel. The binnacle is sometimes made with three divisions instead of two, in which case a compass is placed in the two outer divisions, and the light between them; but this method is objectionable, because the needles are liable to act upon each other. The light is often thrown upon the compass-card very imperfectly, and may also be seen at a distance from the ship, which is an objection.

Mr. Preston's binnacle has a cylindrical top for enclosing the lamp in a case, so that it can be lighted below in bad weather. The light is powerful and steady, and is thrown vertically upon the compass-card, and the expenditure of oil is small. No direct light is seen, to dazzle the eye of the steersman, nor is any light shown which can be seen by the enemy at sea.

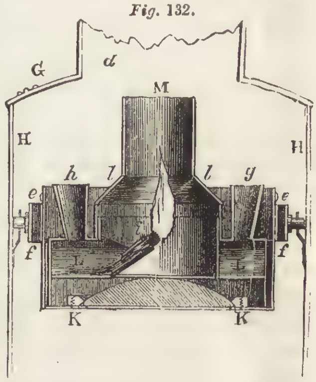
Fig. 131 represents this binnacle as it stands upon the deck of a vessel, opposite to the steering-wheel. Fig. 132 is a section of the box containing the lamp and reflector. A A is a square box closed by a door in front, but omitted in the figure in order to show the interior. This box is fixed down, with the two sides parallel with the ship's keel. B is a shelf in the box, to support a board C, which exactly fits the box, but has its angles taken off, to allow it to slide in and out freely: it has a stem *a*, of brass wire, standing up from the centre, and terminating in a sharp point, on which

Fig. 131.



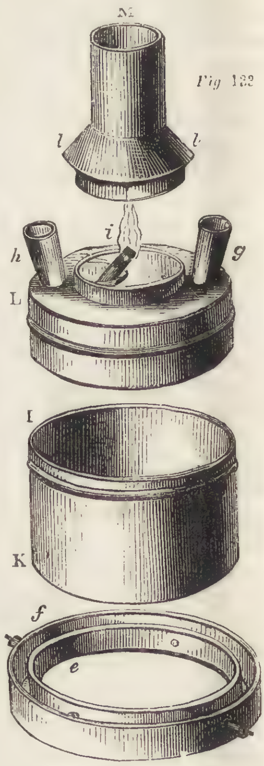
the compass-card is freely suspended to turn round; being then included within a circular opening made through the top of the box, and its divisions reading against the *lubber's point*, drawn on a piece of white paper, and seen plainly in the figure. The opening in the top of the box is surrounded by an octagonal lantern, which has glass panes in all its sides, which are closed at night by sliding shutters *a a*. The compass is seen through the glass *b*, placed at a proper inclination to command the view of the card. The lamp is situated in a circular box, fitted with a ring F at the top of the lantern-frame, and as a dome G, with a chimney *d* to carry off the smoke. The section, Fig. 132, will explain the interior parts. H H are the sides of the cylindrical box which fits into the ring *f*, Fig. 133. *e e f f* are the sections of two brass circles or gimbals, shown separately in Fig. 133.

Fig. 132.



The external one has two projecting points, which are received in pieces of copper, soldered to the inside of the box; the internal ring has similar pivots, but these are received into holes in the outer ring, the direction of the two lines of pivots being at right angles to each other, so that the interior ring, and all that it supports, has a universal motion, and, if properly balanced, will preserve its horizontal position in any inclination of the box. I K is a brass box, shown separately, fitting the ring *f*, and in the bottom is a large plano-convex lens, K K, which concentrates the light of the lamp, and throws it down upon the card. The lamp L is just within the box: it consists of a deep hollow hoop of copper, L, Fig. 133, for containing the oil, which is poured in by two tubes, *g h*. The wick *i* is contained in a narrow spout proceeding from the interior to the centre of the hoop, and the flame projects over the end of the spout. The conical chimney M includes a reflector of tinned iron, well polished, which reflects

Fig. 133



the light downwards. By these means the card is well illuminated, and if the shutters *a a* be put down, no light escapes except at the aperture *b*, and this directs the light upwards in a direction in which it will not fall upon any part of the ship.

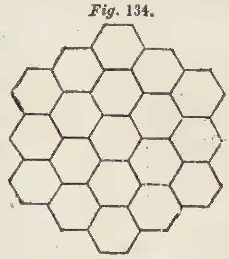
BIRD-LIME. This substance is now in great part imported into England from Turkey, but was formerly manufactured here to a considerable extent, and exported to India for the purpose of destroying insects. It is a green substance, viscid and tenacious, made from the bark of various shrubs, but chiefly from that of the common holly. It may also be made from mistletoe and other parasites. It contains a resin (which has been called *viscine*), mucilage, colouring and extractive matter, and a little free acid. The middle bark of the holly contains a large amount of viscid matter, and from this, and the bark stripped from the young shoots, the best birdlime is made. The bark is boiled six or eight hours in water, until tender; it is then drained from the water, and laid in pits, for two or three weeks, to ferment, being occasionally moistened with water, if necessary. After this it is taken out, and reduced to a paste by pounding in mortars, then washed and kneaded, and packed in earthen vessels. After three or four days, during which it ferments and purifies itself, it is fit for use.

BISCUIT (Latin, *bis coctus*, twice baked). An unfermented bread, which, if properly prepared, can be kept for a great length of time, and hence its use as a common form of bread at sea. At present the ships of the Royal Navy are supplied with biscuits made by machinery, before the introduction of which they were made by hand in the following manner. A gang of five men were employed, who were severally named, the *furner*, the *mate*, the *driver*, the *breakman*, and the *idleman*. The driver made the dough, by mixing the flour and water together in a trough with his naked arms, until, by a laborious operation, a proper consistency was obtained. The rough dough was then deposited on a break, or wooden platform, to be worked by the breakman, who kneaded it by riding or jumping upon it by means of a breakstaff. When sufficiently kneaded, it was taken to a strong table, called the moulding-board, where it was first cut into slips, then divided into lumps of the size of the biscuit, then moulded by hand into the circular shape, and lastly *docked*, or pierced full of holes, by means of a *docker*, the whole of the gang assisting in this operation. The oven being properly heated, the biscuits were pitched in by the joint labours of the furner, the mate, and the idleman. The gang thus produced 100 lbs. weight of biscuit in 36 minutes, including 15 minutes, the time allowed for baking. Hence the nine ovens in the Royal Clarence Victualling Yard at Gosport required the labour of 45 men to keep them in full operation, and the produce was about 14 cwt. of biscuit per hour, at a cost for labour and utensils of 19*d*. per cwt.

The good quality of biscuit chiefly depends on the thorough kneading of the dough, and its subsequent division into portions of equal size and thickness. If the meal be not equally mixed with the water, some portions of the biscuit will be wetter than others, and will require more baking than the dry parts: these will be overbaked or burnt up, or the moist parts will remain unbaked; the biscuit thus becomes *hard* or *flinty*. So also if the biscuits are of unequal thickness, if the thin ones are not overbaked, the thicker must be underbaked; and the thin parts of a badly moulded biscuit will *perish* from the action of the fire, while its thick part is converted into *flint*.

About the year 1833 this method was superseded by machinery contrived for the purpose by Mr. Grant, of Gosport. In the first process, the meal is conveyed into a cylinder 4½ feet long, 3 feet 2 inches in diameter, and the water is let in from a cistern at the back of the cylinder, regulated by a gauge to the exact quantity required for mixing the meal. Through the centre of the cylinder is fitted a shaft armed with knives, and working horizontally. The shaft being set in motion, the knives revolve through the meal and water. During the first half-minute the meal and water do not appear to unite; but after this the dough begins to assume a consistency, and in two minutes 5 cwt. of well mixed dough is produced. The cylinder is formed so that its lower half is easily separated by means of a wheel and pinion from the upper sides, thereby forming a trough containing the dough, from which it is removed, and placed under the breaking-rollers to be kneaded. These rollers, two in number, weigh 1,500 pounds each, and are propelled from off a two-throw crank-shaft by means of connecting rods and pendulums; they pass backwards and forwards over the dough during five minutes, when the 5 cwt. of dough is brought into a solid, perfect, and equal consistency. From the breaking-rollers the dough is cut into pieces 18 inches square, and placed on boards 6 feet long by 3 feet wide, which are conveyed by means of a line of friction-rollers connected by an endless chain under a second set of rollers, to be rolled to the required thickness of the biscuit. The square of dough being thus pressed out, so as to cover the surface of the board, on which it is transferred under the cutting and stamping-plate, is at the same moment cut and stamped, or *docked*, into 42 hexagonal biscuits, which, being now complete, are at once conveyed to the oven on carriages constructed for the purpose. The hexagonal shape is preferred in order that there may be no waste, the sides of each biscuit by this contrivance fitting accurately into those of the adjoining biscuits, as seen in Fig. 134. Each biscuit is stamped with the broad arrow, the number of the oven, and also docked by the same movement which cuts it out of the piece of dough. The hexagonal cutters do not completely separate the biscuits, so that a whole sheet of them can be put into the oven at once, and after being withdrawn, they are broken asunder by hand.

Fig. 134.



The corn for the biscuits is prepared at the Government mills : it is a mixture of fine flour and middlings. [See BREAD.] The ovens are of wrought-iron, with an area of about 160 square feet. About 112 lbs. weight of biscuits is put into the oven at one time : this is called a *suit*, and is reduced to about 100 lbs. by the baking. The men engaged in this work wear clean check shirts, and white linen trousers, apron, and cap ; and the most scrupulous attention to cleanliness is observed.

The bakehouse at Gosport was provided with one mixing-machine, two breaking-rollers, four sheet-rollers, and four stampers ; and it was calculated that this machinery would require eight men and eight boys, to supply the nine ovens ; that the produce per hour would be 10,000 biscuits, or one ton of bread, at a cost for labour and other incidental expenses of 5¼*d*. per cwt. It was found, however, in practice, that the machinery could easily supply eighteen ovens, should it ever be advisable to enlarge the bakehouse to that extent. With the exception of the men employed in heating and managing the ovens, no professional bakers are required, ordinary labourers and boys being fully competent to every other part of the work. This is a great advantage, since, in time of war, it has hitherto been found very difficult to supply the navy with biscuit, and the men employed as biscuit-bakers required very high wages. In the late war, double gangs of workmen were constantly employed ; but the supply of biscuit was so inadequate that the Government was compelled to have recourse to contractors, who supplied bad biscuit at a high price. It has been calculated that the three bakehouses at Deptford, Gosport, and Plymouth, could, by working eight hours per day, produce annually 7,354 tons of biscuit. If this quantity had to be made by hand, the price paid for labour and utensils, at 19*d*. per cwt., would amount to 11,643*l*. The machinery manufactures at 5¼*d*. per cwt., including 10 per cent. for wear and tear, and all other expenses ; so that this same quantity of biscuit would be produced for 3,217*l*., showing a net saving of 8,426*l*.[1]

The term *biscuit* is also applied to porcelain, when baked and not glazed. [See POTTERY and PORCELAIN.]

BISMUTH. A metal of no great importance in the arts. It was first distinguished from lead by Agricola, in the 16th century. It is found native, and also in combination with oxygen, with arsenic and sulphur. It is found in very limited quantities in Cornwall, Germany, France, and Sweden. In the smelting works of the Saxon Erzegebirge, at Schneeberg, the metal is separated from its gangue by a very simple process. The ore is enclosed in tubes of iron plate, (Fig. 135), placed in an inclined position. The mineral is introduced by the opening at P, which is then shut. The other extremity is closed by a plate with a small aperture near the lower edge, through which the metal flows out as it is melted by the action of the heat. It is received into clay pots *c* on the outside, which are kept hot by a fire beneath them. From these pots the metal is ladled into moulds. In this state it is always contaminated by sulphur and arsenic, which, however, can be separated by fusing the metal with $\frac{1}{10}$th of its weight of nitre.

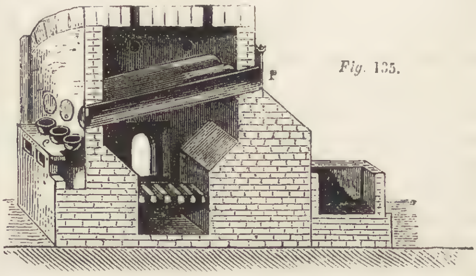


Fig. 135.

Bismuth (Bi 213) is a brittle white metal, with a slight red tint, which is very evident in holding a specimen by the side of a lump of antimony or zinc. Its specific gravity is 9.822. It fuses at 476°, or according to another authority 507°, and always crystallizes in cooling. It expands at the moment when it solidifies, so that it is lighter in the solid than in the liquid state. Good crystals may be obtained by carefully melting the purified metal, and then pouring it into a heated mould, and allowing it to cool very slowly and quietly. When a solid crust has formed on the surface, it is pierced in two opposite places near the edge, and the liquid metal is poured out at one hole, while the air enters at the other. The mould is then suffered to cool, and on removing the crust the cavity will be found lined with beautiful cubical crystals (Fig. 136), highly iridescent from the formation of a thin pellicle of oxide on the surface, at the moment when the hot metal comes in contact with the air. Bismuth transmits heat more slowly than most other metals, probably on account of its highly crystalline texture. It is volatile at a high temperature, and may be distilled in close vessels, but with difficulty. A cast bar of bismuth $\frac{1}{10}$th inch in diameter supports a weight of 48 lbs.

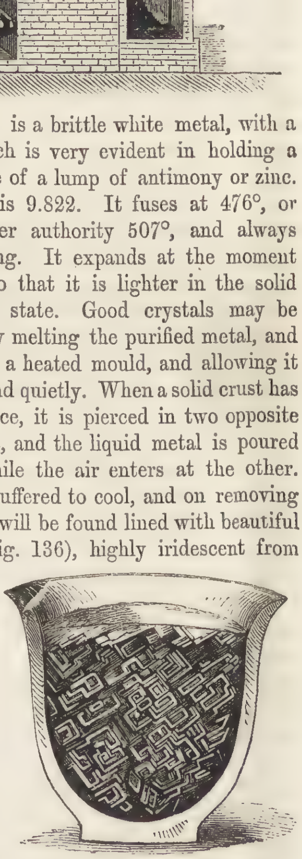


Fig. 136.

There are three oxides of bismuth, the sub-oxide, the oxide, and the superoxide. The oxide may be obtained by dissolving bismuth in nitric acid, and fusing the precipitate of subnitrate thrown down by water. This subnitrate, also called *pearl-white*, is used by some ladies as a cosmetic. It is more usefully employed as a flux for certain enamels, increasing their fusibility without imparting colour. It is hence used as a vehicle for the colours of other metallic oxides. When well washed it is employed in gilding processes, an addition of $\frac{1}{15}$th being made to the gold. It is also used in medicine.

Some of the alloys of bismuth were noticed under ALLOY. In this article it was stated that

(1) Nautical Magazine, vol. i. New Series. 1837.

safety plugs of fusible metal formed of lead, tin, and bismuth have been used in steam boilers to provide against explosion. It was supposed that if the temperature of the steam should rise above a certain point, and the safety valve not be in a condition to allow of its escape, the plug would fuse, and afford a vent. It has been found, however, that when this alloy is exposed during a long period to a temperature near its fusing point, it undergoes a sort of *eliquation*, [See ASSAYING,] by which a more fusible alloy is melted out, and that which remains is much less fusible than the original alloy. In some explosions of boilers, the safety plugs have for this reason been found entire. Hence this mode of protecting boilers has been abandoned.

Fusible metal has been successfully employed for making casts of anatomical preparations, and other similar purposes. Professor Brande says:—"It may be employed for taking casts from medals, and even from the surface of wood and embossed paper. Some beautiful casts have also been made in this metal of the internal ear, showing the complexities of its bony cavities." Cake moulds for the manufacturers of toilet soaps are also made of this metal.

BITTERN. The mother-liquor or uncrystallizable residuary solution of SALT WORKS, so called on account of its excessively bitter taste. Its principal ingredients are chloride of magnesium and sulphate of magnesia or EPSOM SALTS.

BITUMEN. [See ASPHALTUM.]

BLACK-LEAD. PLUMBAGO. GRAPHITE. A mineral substance occurring in veins, and in kidney-shaped lumps, in gneiss, mica slate, and their subordinate rocks; also in transition slate, as in the valuable mine at Borrowdale, in the heart of the lake district of Cumberland. Black-lead has probably received its name from its colour, which is of a leaden or slaty grey, passing into iron black, but there is not a particle of lead in its composition. According to Vanuxen, the pure and impure varieties from Borrowdale contain:—

	Pure.	Impure.
Carbon	88.37	61.27
Water	1.23	5.33
Silica	5.10	10.10
Alumina	1.00	3.20
Oxides of iron and manganese	3.60	20.00
	99.30	99.90

The ashes of plumbago are found to contain titanic acid, and "it seems probable," says Brande, "that in plumbago the oxide of iron is in combination with titanic acid and silica, and not with the carbon, so as to constitute a carburet of iron." Some specimens, as those from Barreros in Brazil, scarely contain a trace of iron.

Black-lead has been found among the coal-strata, as at Cumnock in Ayrshire; it has also been found in greater or less purity, and occasionally worked in many other parts of the world, especially in the United States of America; but the English mine at Borrowdale has long maintained the pre-eminence, so that the "*crayons d'Angleterre*" are in great esteem throughout the continent. The Borrowdale mine was discovered in the reign of Elizabeth, and soon became celebrated for its valuable contents. The work-people engaged in it, and those from neighbouring mines, were not proof against the temptations to plunder. The latter would even cut their way through from their own mines, and carry off quantities of the black-lead. On one occasion a party of miners overcame the guard placed at the entrance, and kept possession of the whole place for several days. These depredations were resisted with difficulty, and were not put a stop to until many persons in the vicinity of the mines had become enriched thereby. At length an act of parliament was obtained, inflicting severe penalties on depredators, and this, with improved means of defence, has proved an efficient protection.

The mine is situated about half way up the side of a mountain called Seatallor Fell, in Cumberland, eight miles south of Keswick, and which rises to the height of 2,000 feet. From the entrance to the mine a horizontal cavity is excavated to the extent of several hundred feet into the body of the mountain, having a railway laid down for the transit of the ore. The entrance is protected by a substantial building, in which is a room for assorting and dressing the ore, which process is performed under strict surveillance, and with the threatening aspect of firearms. These is also a room called the dressing-room, in which the workpeople change their garments previous to entering the mine, and again after six hours' work, on leaving. In this room is a trap-door which forms the miners' only means of entrance to the mountain. The plumbago is of a fine granular texture, and so pure that it requires very little labour to fit it for the market. When it has been assorted and dressed, it is packed in strong casks holding about a hundredweight each, and is thus forwarded to the proprietors in London. In former times this mine was only opened once in seven years, but owing to the increased demand for plumbago, it is now opened every summer for about six weeks, and during that short period as much as 30,000*l.* or 40,000*l.* worth of mineral is sometimes obtained. The closing of the mine is accompanied with laborious precautions for insuring its safety. The earth and rubbish previously excavated are wheeled back again to the opening of the mine, and heaped up there to the amount of some hundred cart-loads. This forms a dam to a rill of water which flows through the mine, and which being thus deprived of the means of outlet, rises to a considerable height, floods the mine, and affords the best protection against robbery.

This important mine is shared between a few individuals, and the product fetches from 35*s.* to 45*s.* per lb. in the market. The market for black-lead is held monthly in London, at Essex Street, Strand. Specimens of the different qualities 3 or 4 inches long are exhibited to the seven or eight individuals

who are the sole purchasers; and after being examined with a sharp instrument to ascertain the hardness, the choice is made, and the order given, the first choice being, however, accompanied with a higher price than the rest. But as there is no addition made to the quantity of black-lead during the year, it comes to pass, that at succeeding markets the specimens which had been previously rejected are all chosen in turn, until the whole is disposed of.

There are several mines of plumbago in the United States of America, the most important being that at Sturbridge, Massachusetts. The plumbago thence obtained is in large masses, in veins, in gneiss, and is coarsely granular and foliated in texture. The quantity annually procured amounts to about 30 tons. At Taunton, Massachusetts, the Sturbridge plumbago is prepared by first pulverising it, and then, by machine pressure, condensing it into thin sheets. These sheets are then sawn up of the size required. This resembles the French method, by which graphite even of coarse qualities is made useful by being ground fine and calcined, but in this latter case it is mixed in a paste with very fine clay, and lamp-black is occasionally added.

The purity of the English mineral enables the manufacturer to apply it to use by simply sawing out slender parallelopipeds, from 1 to 2 inches long, from sound pieces of plumbago which have been previously calcined in close vessels at a bright red heat. These parallelopipeds, enclosed in cases of cedar, form the best black-lead pencils. But they may be also used alone, being protruded as they are wanted from slender tubes, by means of an iron wire and screw contained in the new form of pencil case adopted of late years, and called the ever-pointed pencil. The cedar cases are made by cutting the wood with a circular saw into four-sided strips of a proper length, and these are arranged so that the thickness of two of them may form a square, of which one piece is thicker than the other, and is grooved by a common plough plane to receive the lead. This is first dipped in glue, and then adjusted to the groove, portion after portion, till the whole of the groove is filled. The surface is then smoothed down level, and the other half of the cedar is glued on, thus making a square black-lead pencil. To make this round, it is passed through a hole in an iron or steel puppet of the exact size of the pencil, and forced along by the workman. On the other side of this hole is an apparatus consisting of two gauges, and a small plane iron, revolving round an open centre, and cutting the pencil into a cylindrical form as it passes along towards a circular hole which next receives the newly fashioned pencil, and further compresses and polishes it before it is finally withdrawn by the workman with a pair of wooden nippers. To prepare the cylindrical leads for ever-pointed pencils is a work of much delicacy. The black-lead, first cut into square prisms, is ingeniously and gradually brought into the required form, by passing it through three different sized circular holes cut in pieces of ruby; the first converts the square into an eight-sided prism; the second changes the eight-sided to a sixteen-sided prism; the third converts it into a cylindrical form, and is of the exact size. The rubies in this operation do not last many days, and steel it is said is worn out in a few hours, so that the ever-pointed pencils, if genuine, can never be very cheap. Yet thousands of pencils resembling these, but made of composition instead of pure lead, are sold at an exceedingly low price.

The first attempt at artificial pencils which led to any important results was that of a French gentleman, named Conté, whose process has been already alluded to. The admixture of pure clay in various proportions, not only with black-lead reduced to powder, but with different coloured earths, enabled him to produce various degrees of hardness and tint which were highly advantageous, and caused these pencils to become celebrated, and to yield to the inventor and his family a handsome fortune. The clay was first carefully washed and diffused in large tubs of river water, and allowed to settle two minutes, when the milky liquor was drawn off from near the surface into the second tub, which thus received only the finest particles. The sediment in this second tub is extremely soft and plastic, and when dried on linen filters, is fit for use. Meanwhile, the plumbago has been powdered in an iron mortar, and calcined in a crucible to nearly a white heat. It is then ready to be mixed with the clay in varying proportions, a fine hard pencil being produced by 2 parts clay to 1 part plumbago, a softer pencil by equal parts of each. The powders when mixed are triturated with water to a smooth paste, and ground with a muller on a porphyry slab till they are of the consistence of thin dough. This dough is pressed into grooves in a smooth board, (previously boiled in grease to prevent the clay sticking to it,) and another board screwed down upon it, so that the air can only act on the ends of the pencils in the grooves, which accordingly contract and become loose in the grooves. The mould is put into an oven at a moderate heat further to dry the pencils, which are then taken out and still further hardened by setting them upright in a crucible, having a luted cover, surrounding them with sand or charcoal powder, and placing them in a furnace, where they are baked more or less, according to the degree of hardness required, and when withdrawn are allowed to cool in the crucible. They are now ready for being placed in the cedar cases, but if intended for very fine work, (architectural drawing, for instance,) they must be first heated and then immersed in melted wax or suet, nearly boiling hot, before being fixed in the case. This gives them a certain degree of softness, and preserves their points better. The hardest pencils of the architect have, however, been made of lead melted with some antimony and a little mercury. The common pencils sold in the streets of London are made with the powder of black-lead, mixed with melted sulphur, and poured into moulds which are sometimes reed or rushes. Common carpenter's pencils are of this sort and answer very well for the

purposes to which they are applied. Gum arabic and resin are often mixed with the plumbago in common pencils.

Besides the principal use of black-lead in making pencils, it is also employed for counteracting friction, for making crucibles and portable furnaces, and for giving a gloss to the surface of cast-iron. The inferior descriptions of plumbago are largely employed for these purposes.

BLACKING. An article prepared in various ways for the blacking of boots and shoes. Each manufacturer has his own recipe, in which the principal ingredients are oil, vinegar, and ivory-black, or some other sort of blacking matter. In former days shoe-blacks stood in our streets to perform the required operation on pedestrians, but in these days of improved pavements, and greater cleanliness, the brilliancy of the shoe that has received its morning polish at home, is scarcely impaired through the day. Blacking is either liquid or in the form of a paste, and some of the establishments for its manufacture, especially in London, are on the most extensive scale, and are known by their elaborate system of advertising all over the world. Among the various prescriptions for making liquid or paste blacking, the following, which has the title of "patent," is remarkable for the introduction of caoutchouc, which would tend to make the blacking water-proof:—18 ozs. of caoutchouc are dissolved in 9 lbs. of hot rape oil. Add 60 lbs. ivory black, and 45 lbs. molasses, with 1 lb. finely ground gum arabic previously dissolved in 20 gallons of vinegar of strength No 24. The whole to be well triturated in a paint-mill till smooth. Then add in small successive quantities 12 lbs. sulphuric acid, stirring strongly for half an hour. The stirring to be continued for half an hour a day during a fortnight, when 3 lbs. of gum arabic in fine powder are to be added, and the half-hour's stirring to be continued another fortnight. A fine liquid blacking is then produced, and is ready for use. To make paste blacking, the same ingredients and quantities are employed, except that the gum arabic is dissolved in only 12 lbs. of vinegar instead of 20 gallons, and the paste is ready in a week.

BLANKET. [See Wool and Worsted.]

BLAST. [See Bellows and Blowing Machines.]

BLAST FURNACE. [See Iron.]

BLASTING. [See Mine and Quarry.]

BLEACHING (from the French *blanchir*, to whiten). Calico, muslin, and other cotton fabrics which are sold in a white state, require bleaching, which is also often a preparatory process to dyeing and calico-printing. Linen goods also require bleaching. There is probably no department of the useful arts which has received such direct and obvious benefits from chemical science as the art of bleaching. It was formerly the practice to send all the brown linen manufactured in Scotland to Holland to be bleached. After some preparatory processes, the linen was spread out in bleaching grounds, and sprinkled with pure water several times a-day. In the course of several months' exposure to air, light, and moisture, the goods were bleached. Goods forwarded to Holland in the month of March were usually returned in the following October, but if sent at a later period, they were not returned until the autumn of the following year. The linens thus bleached were called *Hollands*, a name which they still retain.

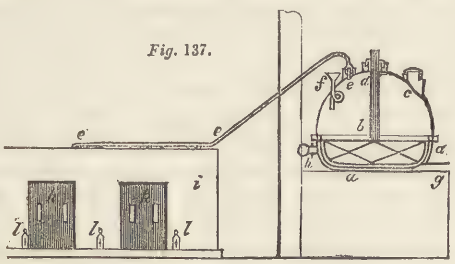
Many attempts were made to introduce the Dutch method of bleaching into this country. In 1749 bleach-works were established in the north of Scotland with tolerable success. The cloth was first steeped for some days in alkaline leys; it was then washed clean and spread upon the grass for some weeks. This *bucking* and *crofting* were repeated five or six times alternately. The cloth was then steeped for some days in sour milk, washed clean and again crofted. These processes were repeated until the linen was sufficiently bleached, the strength of the alkaline ley being gradually diminished.

This method of bleaching was very expensive, not only from the length of time required in the operation, but also from the large extent of grass-land required in crofting. The constant exposure of large quantities of goods out of doors served as a temptation to dishonest persons, and led to much crime and to severe penal laws against the delinquents. Cases have also occurred in which innocent persons have been shot by spring guns or wounded by mantraps, and in one terrible case, a man who was watching his property actually shot his own son, who, after a long absence at sea, was returning home, and walked across the bleach croft as a nearer path to the house.

The first improvement on the old Dutch method, was in the process of *souring*, in which dilute sulphuric acid was substituted for sour milk, the effect of which was to reduce the time required for bleaching, from 8 to 4 months; but the grand improvement in the art was made by Berthollet, who, in 1785, while repeating some experiments on chlorine, which had been discovered by Scheele in 1774, found that an aqueous solution of this substance was capable of destroying vegetable colours, and he was hence led to suggest its application to bleaching. In 1786, Berthollet showed the experiment to Watt, who was then in Paris, and on his return to England he examined the subject practically, and actually bleached 1,500 yards of linen by its means, in the bleach-field of his father-in-law Mr. Macgregor, near Glasgow, who was so well satisfied with the process that he resolved to adopt it at his works. In the following year Professor Copeland of Aberdeen introduced the plan to the bleachers of that neighbourhood, who adopted it gladly. The method soon got into bleach-works generally, but it was found after a short time that the powerful action of the gas was injurious to the workmen, and also to the texture of the goods exposed to it. Berthollet endeavoured to remove the noxious odour by adding potash to the water, by which means a greater quantity of the gas was absorbed, and the solution was then diluted with a considerable quantity of

water. The bleaching property of the solution was however destroyed after a time by this method, in consequence of certain chemical changes which took place. Dr. Henry of Manchester substituted lime for the potash, by first passing the goods to be bleached through a stratum of thin cream of lime, and then exposing them to an atmosphere of chlorine; a chloride of lime was thus formed in the cloth, but its action was in some cases injurious. In 1798 Mr. Tennant of Glasgow took out a patent for a method of making a saturated solution of chloride of lime for bleaching purposes. It was perfectly successful, but the patent was set aside on the ground that the invention was not new. Mr. Tennant, however, continued his investigations, and discovered a method of impregnating lime in a dry state with chlorine, thus producing the celebrated *bleaching powder*, which is prepared at the present day much in the same manner as it was originally contrived. The lime is contained in a stone chamber *i*, (Fig. 137,) 8 or 9 feet high, built of siliceous sand-

Fig. 137.



stone, the joints of which are secured with a cement of pitch, resin and gypsum. A door fitted into it at one end, can be made air-tight by strips of cloth and clay. A window at each side enables the workmen to judge how the impregnation goes on by the colour of the gas, which is yellowish green. The lime to be impregnated with the gas is contained in trays 8 or 10 feet long, 2 feet broad, and 1 inch deep. These trays are arranged one over another to the height of 5 or 6 feet, and are kept about an inch asunder by means of cross bars. The chlorine is obtained from common salt (chloride of sodium), by the action of black oxide of manganese and sulphuric acid. About 10 cwt. of salt are mixed with from 10 to 14 cwt. of manganese, and then introduced by an aperture at *c* into a large leaden vessel of a nearly globular form. This vessel has an outer casing or jacket of iron *a a*, and steam is admitted at *h* into the interval between the two, for the purpose of communicating heat. From 12 to 14 cwt. of sulphuric acid are introduced in successive portions through a twisted funnel *f*, and the materials are all stirred up by means of an agitator *d b*, the handle of which is on the outside. As the gas escapes from this vessel, it is received into a leaden cylinder containing water: it then enters by a leaden pipe *e* into the top of the ceiling of the stove-room *i*, and being heavier than the air of the room, falls slowly down and diffuses itself through the chamber, where it gradually combines with the lime. After the action has been carried on for about 2 days. the half formed chloride within the chamber is stirred up by means of rakes *l l* from the outside, or a man enters the chambers for the purpose by the doors *k k*: by this means the particles of lime which have not yet absorbed the gas are exposed to its action. The process is then continued for another 2 days, the materials in the leaden retort being frequently stirred up. When all the chlorine is extracted, the contents of the retort, consisting of sulphate of soda and sulphate of manganese, are removed by the tube *g*.

The chloride of lime thus formed, is used in enormous quantities in the bleach-works of Great Britain, most of which are situated in Lancashire and in the neighbourhood of Glasgow. As the various processes require an abundant supply of pure water, the works are usually situated near some stream. The substances which require to be removed from cotton goods in order that they may have a pure white colour, are of various kinds. The cotton fibres are covered with a resinous substance, which to a certain extent prevents the absorption of moisture, and also with a yellow colouring matter, which in some kinds of cotton is so marked as to give a distinctive character to the fabric made from it, as in *mankin* or *nankeen*, which is manufactured in China, from a native cotton of a brown yellow hue. Neither the resinous nor the colouring matter has any influence on the strength of the fibre, for the yarn spun from it is as strong after bleaching as before. In some varieties of cotton, the quantity of colouring matter is so small, that the fabric would not require bleaching were it not for the impurities acquired in spinning and weaving. The weavers' dressing of paste, and the rancid tallow or butter used to soften it when it becomes dry, certain soapy and earthy matters, and the dirt of the hands, all require to be removed.

As soon as the goods are received at the bleach-works, the end of every piece is marked with the proprietor's name, which is done with a needle and thread, or with a wooden stamp moistened with coal tar. The fibrous down or nap on the surface of the goods is then burnt off by a process called *singeing*, which greatly improves their appearance, and in the case of dyeing or printing enables the cloth to receive the dye or pattern more perfectly. In this process a number of pieces of cloth are fastened together at the ends by means of long wires, and then wound upon a roller furnished with a winch. The cloth is then drawn over a half cylinder of copper made red-hot by being built into a horizontal flue (Fig. 138). As soon as the cloth has passed over the heated metal, it is wound upon a second roller which plays in a trough of water. The cloth is usually passed three times over the hot surface, twice on the face or the side intended for printing on, and once on the back. It is wound from one roller over the heated metal to another roller on the other side of the furnace, a swing frame being placed for raising the cloth at any moment out of contact with the heated metal, and water is at hand in case of accident to the goods, which is a rare occurrence. By this

operation the goods become browned and discoloured. Gas flames are used for singeing thread, muslins, and bobbin-net lace. The flames issue from numerous perforations in the upper surface of a horizontal tube,

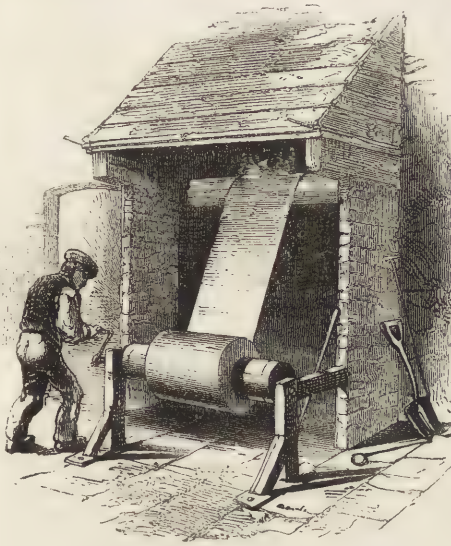


Fig. 138. SINGEING COTTON GOODS.

and the fabric to be singed is drawn over the flame upon rollers with a rapidity adapted to the texture of the goods. The flame is drawn up through the web by placing immediately over the gas-flame a horizontal tube with a slit in its lower surface. This tube is connected with a fan or other apparatus for withdrawing the air from it, and thus increasing the draught of the flame.

After singeing, the cloth is steeped in a cistern of water, and, in order to ensure contact with the water, each piece is pulled out, folded loosely, and tied up, with a noose at the end, into an irregular

Fig. 139. DASH-WHEELS.

bundle. After soaking 12 or 14 hours, the pieces are washed in a *dash* or *wash-wheel*, which is a hollow, circular, perpendicular wheel, 5 or 6 feet in diameter, and nearly 2 feet in depth. It is divided into four equal compartments by partitions proceeding from the axis to the circumference, each of which has a circular opening on one face of the wheel. (Fig. 139.) Water is admitted into the compartments by a pipe concentric with the axis on which the wheel rotates. The pieces to be washed are put into the compartments through the circular openings in front, and water being admitted, the wheel is made to rotate rapidly, and thus wash the cloth with considerable agitation. The object of this washing is to remove as much of the dirt and weavers' dressing as possible; but, as the grease cannot be removed except by making it soluble by the action of an alkali, lime is economically employed. The pieces are therefore boiled with lime in a large circular boiler, or keir, called a *bucking* or *bowking-keir*, or *puffer*, shown in section in Fig. 140, while in Fig. 141 one of these keirs is represented in action, and another in the course of preparation. It consists of a pan of wrought-iron, set in brickwork, on which the fire acts, and an upper part of cast-iron for containing the goods. The two parts are separated

Fig. 140

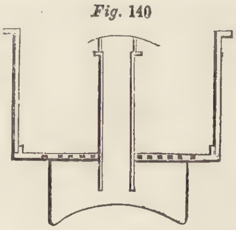


Fig. 141. BUCKING KEIRS.

by a false bottom of cast-iron, and in the centre is an iron pipe furnished with a curved cover. The liquor in the pan, from the pressure of the goods above it, does not boil until it is some degrees above the boiling-point; the liquor boils first in that part of the pipe where the pressure is less than it is in the pan, so that a mixture of steam and water being formed there, rushes up the pipe, and is reflected back by the cap upon the goods, thoroughly drenching them with the hot alkaline liquor. This discharge is followed by another portion of the heated alkaline liquor, which, rising into the pipe, boils and escapes at the top as before. In this way the action goes on, and the liquor, gradually filtering through the goods, finds its way back again into the pan, to be again heated and discharged as before. In preparing a keir, 1 lb. of lime is used for every 30 or 40 lbs. of goods; the lime is formed into a cream in a separate vessel,

and is gradually spread over the goods as they are deposited in layers in the keir; the requisite quantity of water is next added, and heat is applied. The liquor is about two hours in boiling, and the process is continued for about seven hours. The effect of the lime is to darken the colouring matter of the cotton, so that after washing they appear darker than they did before; but all the dirt and grease are removed by this process. The goods are next washed in the dash-wheels, in order to remove the adhering lime, and then comes the *chemicking*, or steeping in a very dilute solution of chloride of lime, for which purpose they are placed in stone vats, over the centre of which is a perforated trough, into which the bleaching solution is pumped up many times during the process, and from this it drains down upon the goods. Every pound of cloth requires about half a pound of chloride of lime, of a certain strength, mixed with about three gallons of water. The steeping is continued six hours, after which the cloth is of a light grey colour, not white, but considerably improved in appearance. Care must be taken to make the steep of the proper strength, for if too strong, the calico will run into holes.

In the next process, which is called *souring*, the goods are steeped for four hours in water soured by sulphuric acid, when a minute disengagement of chlorine takes place throughout the substance of the cloth, and it immediately assumes a bleached appearance. The acid also removes a small portion of oxide of iron contained in the fibre, and also the lime of the previous processes. When removed from the acid, the goods are again washed: they are greatly improved in appearance, but still not quite bleached. They are therefore boiled for eight or nine hours in a potash or soda ley; then washed at the dash-wheel; again steeped for five or six hours in a solution of bleaching-powder, two-thirds of the strength of the first solution; then soured as before for two, three, or four hours, according to the quality of the goods, and at length they are perfectly bleached. Every trace of acid is removed by careful washing, for if any acid were left in the cloth, it would corrode it, especially when heated. The acid favours the bleaching action, and does not injure the fibre of the cloth, although the steeping is continued for days, provided the cloth is not allowed to dry with the acid in it, or be left above the surface of the liquor. The acid is also necessary to remove the caustic alkali, which adheres with great pertinacity to the goods. The goods lose weight in being bleached. Fine calico loses nearly 10 per cent.; but of this, one-half is the weavers' dressing. In coarse goods the loss is greater. For the processes subsequent to bleaching we must refer to the article CALENDERING.

The above details refer chiefly to cotton shirting, and the better descriptions of calico used for printing on. The processes are modified for different varieties of cotton goods. It is also often necessary to expedite the various processes. As an example of the rapidity of bleaching by the new method, compared with the old, we may mention one case in which a Lancashire bleacher received 1,400 pieces of grey muslin on a Tuesday, and on the Thursday following they were returned bleached to the manufacturers, at the distance of sixteen miles, and were packed up and sent off on the same day to a foreign market.

In bleaching linen, the processes are similar to those already given, but are continued longer on account of the firmer hold which the colouring matter has on flax. This colouring matter does not appear to be chemically combined with the fibre until the plant is steeped in water, in the process of *retting* (FLAX). Hence, to save the expense of bleaching, it has been proposed to separate the woody fibre by drying the plant, instead of steeping it, and then to beat off the woody parts by means of mallets. The linen can then be bleached by a simple washing in water.

In all these processes the efficient bleaching agent is the chlorine, but the precise method in which it acts is not well understood. Perfectly dry chlorine does not bleach at all; but when dissolved in water, its bleaching power seems to arise from its decomposing a portion of the water, the oxygen of which unites with the colouring matter, and renders it soluble in water or a weak acid solution. The bleaching power of dew and of rain-water is referred to the excess of free oxygen which they contain. But according to another view, the organic colouring matters being compounds of carbon, hydrogen, oxygen, and sometimes nitrogen, the chlorine acts directly upon them with decomposition, uniting with the hydrogen to form hydrochloric acid, and setting the other components free, or rendering them soluble. For example, writing-ink is a compound of sesquioxide of iron and an organic substance named *tannin*. The chlorine will combine with the tannin or one of its elements, and cause the written characters to disappear. If the paper be now moistened with a solution of prussiate of potash, it will unite with the sesquioxide of iron, and the characters will reappear. If, however, after the tannin has been removed by the chlorine, the paper be washed over several times with very dilute hydrochloric acid, the writing will be completely destroyed. Chlorine has no action on Indian ink or on printer's ink, because the colouring matter in these cases is minutely divided carbon, which does not combine directly with chlorine.

Bleaching powder varies greatly in strength, and it is of importance to the manufacturer to be able to determine its value, or the quantity of chlorine contained in a given sample. Many methods have been recommended for this purpose. Professor Graham's method is simple in practice, and depends on the effect of the chlorine of the bleaching-powder in peroxidizing a proto-salt of iron, of which two equivalents require one of chlorine. The chlorine acts by decomposing water, and liberating a corresponding quantity of oxygen. 78 grains of green sulphate of iron are dissolved in about 2 ounces of water, and acidulated by a few drops of sulphuric or hydrochloric acid. This quantity will require for peroxidation exactly 10 grains of chlorine. 50 grains of the bleaching-

powder to be examined are next rubbed up with a little tepid water, and transferred to an alkalimeter, [see ALKALIMETRY], which is filled up to zero with water, and the contents well mixed by agitation. "The solution of chloride of lime being thus made up to 100 measures, is poured gradually into the solution of sulphate of iron, till the latter is completely peroxidized, and the number of measures of chloride required to produce that effect observed. The change in the degree of oxidation of the iron solution is discovered by means of red prussiate of potash, which gives a precipitate of prussian blue with a salt of the protoxide of iron only, and not with a salt of the peroxide. By means of a glass stirrer, a white stoneware plate is spotted over with small drops of the prussiate. A drop of the iron solution is mixed with one of these after every addition of chloride of lime, and the additions continued so long as a deep blue precipitate is produced. The liquid may continue to be coloured green by the iron salt, but that is of no moment. The richer the specimen of chloride of lime is in chlorine, the fewer measures of its solution are required to peroxidize the iron, the number of measures containing 10 grains of chlorine always producing that effect. The quantity of chlorine in the 50 grains of bleaching-powder is now known, being ascertained by the proportion, as the number of measures poured out of the alkalimeter is to 10 grains of chlorine, so 100 is to the total grains of chlorine. In a particular experiment, the 78 grains of sulphate of iron required 72 measures of the bleaching solution. Hence, as 72 is to 10, so 100 is to 13.89 chlorine in 50 grains of the chloride of lime. The quantity of chlorine in 100 grains of the chloride, or the per centage of chlorine, is obtained by doubling that number, and was therefore in this instance 27.78 per cent. or 28 per cent." [1]

According to Professor Brande, "the best samples of commercial chloride of lime contain on the average not more than 30 per cent. of chlorine, and when chlorine is passed over hydrate of lime, in an experiment upon the small scale, it cannot be made to absorb more than about 40 per cent.; but if the hydrate of lime be diffused through water, it will then absorb more than its own weight of chlorine, and we form a solution containing one equivalent of lime (or of hydrate of lime) and one of chlorine, which is the true atomic compound, and is dissolved out of bleaching-powder by the action of water." [2]

The bleaching of wool is performed by a process called *sulphuring*, in a close apartment in which sulphur is burning. The goods are hung on poles, so disposed that the sulphurous acid can readily penetrate them. When the chamber is filled, a quantity of sulphur is placed in flat broad dishes, and, being ignited, it is allowed to burn away gradually, and in the course of some hours the colouring matter is destroyed. In bleaching mousselins de laines (which are formed of cotton and wool), the goods are usually passed two or three times through a solution of soap and soda at about the temperature of 130°, and then sulphured for several hours. After this they are passed through a very weak solution of caustic soda, dried, and usually impregnated with a dilute solution of tin, which imparts considerable brilliancy to the colours afterwards applied to the goods.

Other varieties of bleaching will be noticed under the articles, PAPER, SILK, WAX, &c.

BLENDE. The native sulphuret of zinc, called by the miners *black-jack*. [See ZINC.]

BLOCK. A block is a pulley or *sheave*, revolving on a fixed axis or *pin* within a chamber or *mortice*, cut out of a solid block of elm, ash, or other tough wood, which is called the *shell*. The sheave is a circular piece of wood, usually lignum vitæ, but sometimes of brass or cast metal, with a groove on the edge for the reception of the rope. In the best blocks, called *coaked* sheaves, the sheave has a brass bush fitted in the centre, with a hole through it for the pin, as in Fig. 142. The pin is usually of iron, but sometimes of lignum vitæ, or other hard wood. It is supported by passing through the sides of the shell. Some blocks are made

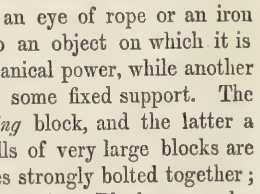
Fig. 142.

to accommodate 2, 3, and even 4 sheaves, in which case there are as many separate mortices. If the sheaves are placed side by side the same pin serves, but if placed one above the other, then of course there are separate pins. In nautical language the block with its rope is called a *tackle* of single or double blocks. Each block is furnished with a band or strap, terminating in an eye of rope or an iron hook, for attaching it to an object on which it is intended to act as a mechanical power, while another block is suspended from some fixed support. The former is called a *running* block, and the latter a *standing* block. The shells of very large blocks are made up of separate pieces strongly bolted together; these are termed *made* blocks. Blocks are also termed *thick* or *thin*, according as they are adapted to the reception of large or small ropes.

Blocks are chiefly employed in the rigging of ships, to assist in raising or lowering the masts, yards, and sails. They are also available as a mechanical power under a great variety of circumstances. There is a description of block without sheaves, termed *dead-eyes*, used for setting up and fastening shrouds, and other standing rigging, sheaved blocks being chiefly used for the running rigging.

It would be quite impossible within the limits of this article, even if it were desirable, to describe the various forms of blocks used in the navy. A few, however, may be noticed. Fig. 143 is called a *snatch-block*. It consists of a single sheave, with a notch cut through one of the cheeks, to allow the rope to be lifted in and out of the block without putting

Fig. 143.



its end in first. In this example, the strap does not surround the block, but is put through a hole at one

(1) Graham's "Elements of Chemistry."
(2) "Manual of Chemistry." 1848.

end. This is a convenient block for hauling a rope.

In Fig. 144 the block is iron-bound, terminating at the notched end in a swivel hook or an eye-bolt large enough to receive several turns of lashing, by which the block is attached to the fixed support. That part of the strap over the notch in the side lifts up with a hinge, and is confined down when the rope is in the block by a small pin passed through an eye in the hinge part of the strap. The strap at the other part of the block is let into the wood, and is kept to its place by nails. This block is used where a warp or hawser is brought to the capstan.

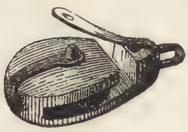


Fig. 144.

Fig. 145 is a *long tackle* block, consisting of two single sheaves, one above the other in the same block. The lower one is $\frac{3}{5}$ the size of the upper; and is used in combination with a common single block to form long tackle for loading or any other purchase.

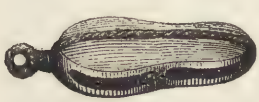


Fig. 145.

Fig. 146 is a *clue garnet* block with a single sheave. This is suspended from the yards by a strap with two eyes, and a lashing surrounding the yard, and passing through the eyes. These blocks receive the clue garnets, or ropes which haul up the clues of the sail, and are applied to the main and fore-yards. Clue-line blocks serve the same purpose, but are applied to the top-sails, top-gallant, and sprit-sails. These blocks were improved by Brunel. In the old form the rope had a tendency to get entangled with the sail, and to slip out of the groove of the sheave. In the improved block two holes are made for the purpose of passing the rope in and out. The sheave is in the centre of the block, so as to be entirely included, except the mortice, where the sheave is put in. The strap surrounds the lower part of the block, and both ends of it pass through the hole in the upper part, where they cross each other; they are then formed into an eye, by which the block is suspended from the yard. In this arrangement the parts cannot get out of place, as the garnet or rope is so much confined within the block, nor can the sail be driven into the block as in the old form.

Fig. 146.

Fig. 147 is a *shoulder* block. A large single block left nearly square at the upper end, and cut sloping in the direction of the sheave. It is used on the lower yard-arms to lead in the top-sail sheets, and on the top-yards to lead in the top-gallant sheets, which by means of the shoulder are kept upright, and prevented from jamming between the block and the yard.

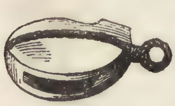
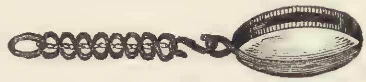


Fig. 147.

Fig. 148 is a *spring* block, invented by Mr. Hopkinson of Philadelphia, to assist a vessel in sailing by increasing the acting spring of her rigging. This consists of a common block with a ring or eye, into which a spiral spring is linked at one end by a hook, and at the other by a ring, which is to be annexed to an eye-bolt at the timber head or other point of application. Two of these blocks are used, one to the timber heads, and the other to the sail. Passing through the spirals of the spring chain is another chain called the check chain, which is connected by links to the hook and to the ring, to prevent the spring being drawn out too far, and thus damaged. Vessels provided with these spring blocks are less liable to heel, and will receive the impulse of the wind to better advantage, but the plan does not seem to have been adopted to any great extent.

Fig. 148.



Among the forms of block used in the navy, some are named after their shape, as D blocks, *Shoe*-blocks, *Nine-pin* blocks. Others are named from a family likeness, as *sister*-blocks, which are two similar single blocks formed out of one solid piece.

Before the introduction of machinery blocks were made in the following manner:—The shells were sawed to the proper length and thickness; the corners were then sawed off; the workman then gauged or marked out the size of the mortice or sheave-hole in the middle, $\frac{1}{16}$th larger than the thickness of the sheave. In single sheaved blocks the thickness was larger than the diameter. In blocks of two or more sheaves the partitions between them were $\frac{1}{6}$th less than each mortice. The block was then jammed up edgewise in a frame, and the mortices gouged out with an auger, and the wood sawed out with a rib saw. The holes were further cleared out by chisels and by burrs at the corners. The pin-hole was next bored through the middle $\frac{1}{10}$th less than the diameter of the pin. The outsides and edges of the block were then rounded off by shaves. The scores or grooves for receiving the strap were made, and the sheaves were then fitted. These were $\frac{1}{10}$th thicker than the diameter of the rope intended to run on them, and 5 times that thickness in diameter. The sheave being nicely bored was put into the lathe and turned smooth, and the groove on its circumference was hollowed out to a depth equal to $\frac{1}{3}$d of its thickness, so that the rope might embrace it closely. The diameter of the pin was that of the thickness of the sheave. The pin was turned cylindrical, except the head, which was left octagonal to prevent it from turning in the block. After the sheave was fitted by driving the pin through the block and sheave, one end of the block was hollowed out to admit the rope, and a small neat chamfer was taken off the edges. The whole block when finished usually formed an oval spheroid flattened at the opposite sides.

The manufacture of an article apparently so trifling as that of a ship's block, seems scarcely to require the assistance of much machinery, or to entail any very great expense on the country; but when it is considered that a single 74-gun ship requires not less than 1,270 blocks, besides 160 dead eyes, and other small articles of a similar kind, all absolutely necessary to the working and even to the safety of a ship, it will readily be supposed how difficult it must be to maintain the supply if made by hand, and how great the expense. The immense demand for blocks during the long protracted war, had called the attention of the Admiralty and Navy Board to the possibility of making some reduction in the expense of this important article. About the year 1801, Mr. M. I. Brunel, an ingenious mechanic from America, had completed models of certain machines for the construction, by an improved method, of the shells and sheaves of blocks. This model was submitted to the Lords of the Admiralty, and by them referred to General Bentham, the Inspector-general of Naval Works. The advantages of machine-made blocks were stated to be, *first*, in ensuring regular and determined dimensions; *secondly*, in adding strength where it was wanted, by making the head and bottom more substantial, and less liable to split; and *thirdly*, in leaving the wood between the two mortices thicker, so as to admit a sufficient bearing for the pins. The uniformity and exactness with which these blocks were to be made would also make it difficult to counterfeit them, and this would act as a precaution against embezzlement. Another great advantage would be the using up of much waste wood in the dockyard, usually sold for a trifle for fire-wood, &c. The sheaves would also be made so true to each other, that every sheave of any particular size would equally fit any shell of the size for which it was intended; and the inconvenience to which ordinary blocks are liable from the friction of the ropes against one or alternately both of the sides of the mortices, was to be removed by placing a sheet of metal on the upper part of the mortice, bent to the proper shape by an engine adapted to the purpose.

General Bentham reported that by the new method there would not only be a great saving, but also an increase of strength, durability, and facility of working in the new blocks. Accordingly, those parts of the machinery which had been secured by patent were removed to Portsmouth in 1804, and were put in operation, while other machines necessary to the completion of the whole scheme were at work by 1808. From that time to the present the whole has gone on without any alteration or assistance from the inventor, and is so complete in all its parts that the attendance of a few common labourers under the direction of the master of the wood-mills is quite sufficient. This collection of machines is one of the most ingenious and complete that was ever invented for forming articles in wood; so that not only blocks, but other articles in wood can be produced, the machines performing most of the practical operations of carpentry with the utmost accuracy and despatch. The largest timber can be converted and sawed up into any scantling, by several circular and reciprocating saws adapted to various purposes. Some of the operations performed by the smaller machines are boring, mortising, turning in wood and iron, riveting, drilling, broaching, burnishing iron pins, &c., operations which were formerly supposed to be chiefly or entirely dependent on the skill and dexterity of the workman. These machines are set in motion by a steam engine of 32-horse power, which is also used for various other purposes in the dockyard. Under this system 4 men can do the work of 50 in making shells, and 6 men can do the work of 60 in making sheaves. These 10 men thus displacing 110 can easily finish in one year 130,000 to 140,000 blocks of different sorts and sizes, of the value of 50,000*l.*, this being the average annual number and value from the year 1808 to the conclusion of the war. Brunel was engaged in completing this system from September 1802 to June 1808, his allowance during that time being 1 guinea a day. On the completion of the system it was agreed that the savings of one year as compared with the contract prices was a fair remuneration. These savings were estimated at 16,621*l.*, to which we may add the six years' allowance at 1 guinea per day, amounting to 2,400*l.*, and for the working model 1,000*l.*, making the total amount received by Brunel about 20,000*l.*, a very fair and moderate remuneration, especially when it is considered that the expenses of the buildings for the new machinery, the machinery itself, the steam-engine, the interest of money, were all completely cleared off by the savings of four years. Such was the importance attached by the government to this invention, that a complete set of duplicate machinery was erected in the Dock Yard at Chatham, and kept in constant readiness for action in case of any accident to the machinery at Portsmouth. Hitherto, however, the duplicate machinery has not been wanted.

The machinery was constructed by Mr. Maudslay, of the Westminster-road, London. The framing of the machinery was of cast-iron, and those parts exposed to violent and rapid motion were of hardened steel. The writer of the article in Rees's Cyclopædia, in which this machinery is minutely described, in speaking of its excellent construction, remarks, that "well-constructed machinery, though expensive in the erection, is cheaper in the end than imperfect works, which require constant repair, the expense of which is the least evil; as it generally happens that a machine will fail at that time when it is most wanted, in consequence of being then most worked; and the loss occasioned by the stoppage of great works, particularly where many people are employed, is too evident to require notice. In the same manner, an attention to neatness in the appearance of machinery has its advantages, by inducing the workmen to be careful of the machines they work at, to preserve them from the slightest injury, and to keep them clean from dust, which, trifling as it may appear, is a very essential point in the preservation

of those parts which are in rapid motion, with friction against other parts, for dust getting between such surfaces grinds them away very fast, and in their most essential points."

We will now notice the machines, and the operations connected therewith, referring to larger works for a more detailed description.[1]

1. *The straight cross-cutting saw.* This is used for cutting up into lengths the elm-trees, of which the shells of the blocks are to be made. The log is introduced through one of the windows of the wood-mill upon a very low bench below the saw, which is lowered, and made to rest with its teeth upon the log, the back being retained in the cleft of the guide. When the crank is set in motion, the saw moves backwards and forwards, exactly as if worked by hand, and quickly cuts through the tree. After the saw has cut to some depth it gets out of the guide, and is sufficiently deep in the wood to guide itself, for in cutting across the grain of the wood it has no tendency to move out of the true line. When the saw has cut off a piece from the log, its handle is caught by a fixed stop, the machine is thrown out of gear, a man lifts up the saw by a rope, and the block is advanced to receive a fresh cut. This saw is used for the largest trees only.

2. *The circular cross-cutting saw,* used for the smaller trees. The axis of this saw is parallel to the length of the tree to be cut; but is so mounted that it can be moved in all directions, either raised up or moved aside; but in all these motions its axis continues parallel to itself, and the saw continues in the same plane. These motions are produced by two winches, each provided with a pair of equal pinions, working a pair of racks fixed upon two long poles. The spindles of these winches are fixed in two vertical posts, which support the axis of the upper frame. One of these pairs of poles is jointed to the extreme end of the upper frame, so that by turning the handle belonging to them the frame and saw are raised or lowered. The other pair of poles is attached to the lower part of the saw frame, so that the saw can be moved sidewise by means of their handles, which then swing the saw from its vertical position. These handles give the workman complete command of the saw. By means of one of them he draws the saw against one side of the tree, which is properly secured, and cuts it about half or one-third through; by the other handle he raises the saw up, draws it against the top of the tree, and cuts it half through from the upper side; he then depresses the saw, and cuts it half through from the next side; and lastly, a trifling cut at the lower side separates the block, and the tree is then advanced for another cut.

3. *The reciprocating ripping-saw* cuts these blocks in the direction of the grain into two, three, or more pieces, in one direction, and then in a direction perpendicular to the former, so as to reduce the logs to the size of the required blocks. The action of this saw is similar to that of No. 1.

4. *The circular ripping-saw,* for smaller sizes than No. 3. This is a thin disc of steel, with teeth formed in its periphery: it is fixed to a horizontal axis just below the surface of a bench, so that a portion of the saw projects through a slit a few inches above the bench. A rapid rotatory motion is given to it by a strap passing over a pulley at the further end of the axis. The workman places the block with one side flat upon the bench, and sliding it forward against the saw, it is cut through with great precision and rapidity.

5. The blocks having been cut to the proper size by the saws, are placed in the *boring-machine,* Fig. 149. This machine has an iron frame A A, with three

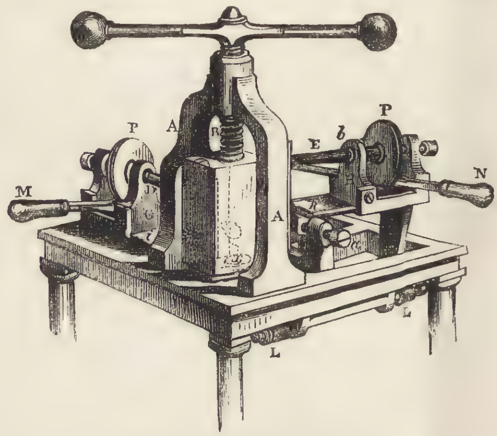
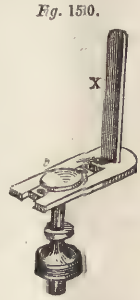


Fig. 149. THE BORING MACHINE.

legs, between which the block is introduced, and the screw B being forced down upon it, confines it to the proper place for the borers D E to act upon it. The end of the screw B has a steel ring fitted upon it, the lower side of which is a sharp edge. When the screw is whirled round, the balls at the end of its cross handle cause it to act as a fly-press, to stamp the impression on the end of the block. The exact position of the block is ascertained by a piece of metal, (Fig. 150,) fixed just beneath the point of the borer E. This piece of metal adjusts the position for the borer D, and its height is regulated by resting on the head of the screw *x*, which fastens the piece X down to the frame. The sides of the block are kept parallel by being applied against the heads of three screws, represented by dotted lines, in the double leg of A. The borer D bores the hole for the centre-pin; the borer E makes the holes for the commencement of the sheave-holes. The borers are of the same form as a carpenter's centre-bit, and each is screwed upon the end of a small mandril mounted in a lathe-frame G and H. These frames are fitted with sliders upon the edges of the flat bars *i k*, the former being secured to the

Fig. 150.



(1) The reader interested in the subject is referred to the 22d volume of Rees's Cyclopædia, and also to the 3d volume of Brewster's Edinburgh Cyclopædia. To the latter authority we are indebted for the description of the illustrative figures of the machines numbered 5 to 9.

frame, and the latter being fixed upon a frame of its own, moving on the centre screws L L, beneath the principal frame of the machine. In this way the borer E can be moved within certain limits, so as to bore holes in different positions, and these limits are determined by two screws, one at *a*, and the other on the opposite side. A projecting piece of metal from the under side of the slider *k* of the borer E stops against the ends of these screws, to limit the excursion of the borer. The frames for both borers are brought up towards the block by the levers M N, which are centred on a pin at the opposite sides of the frame of the machine, and have oblong grooves through them, which receive screw-pins fixed into the frames G and H beneath the pulleys P P, which give motion to the spindles.

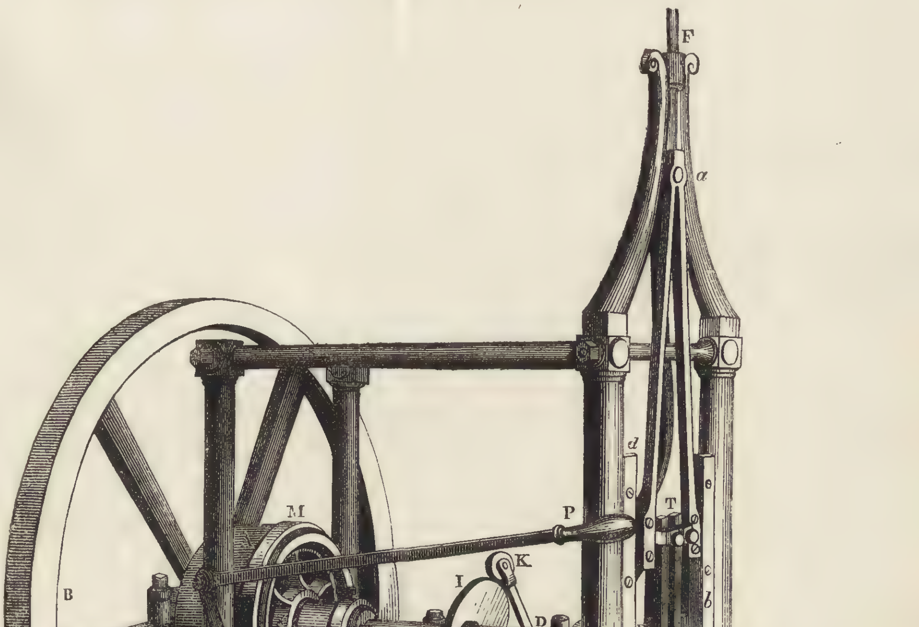


Fig. 151. THE MORTISING MACHINE.

The block being applied with one of its sides against the three screws in the double leg, and resting on the screw *x*, is thrust up against the stop X, Fig. 150. The screw B is then brought down, which holds it fast, and the workman takes the handles M N, and forces them towards the block. This brings the borers against it; and, as they are in rapid motion, they will bore as fast as they can be brought up to the work. This is the method of boring a single sheave block, when the screw-stops at *a* are screwed so far as to confine the frame *k* in a vertical position, and then its borer makes a hole through the centre of the block. For a double block the screws are withdrawn so far that when the frame is held against

one screw its borer will be in the proper place for one hole; and when inclined to the other screw, it will be in the proper place for the other hole; and this distance between the holes can of course be increased or diminished as required to suit thick or thin blocks. The borers can be unscrewed near the ends of their spindles at *b*, to put on one of a larger or smaller size. The points of the screw-centres at L, on which the frame of the borer E vibrates, can be put into different holes in the frame, so as to alter the difference of level between the two borers, to suit blocks of different sizes; and the screw *x* is changed for one with a thicker head, or a washer is put upon its head. The stop X can be altered in position, by sliding it further from or nearer to the frame.

6. The block thus prepared by the boring machine is taken to the *mortising machine*, Fig. 151. This machine is moved by an endless band passing round a drum at A, screwed to a fly-wheel B. This drum turns an axis D, at the extreme end of which is a crank, with a long rod extending from it up to a joint at *a*, by which it is connected with a frame E, fitted between sliders *b d*, and guided by a cylindrical rod F, sliding through a fixed collar. In this way the frame is moved up and down when the axis D revolves. To this frame the chisels are attached, and operate upon the block fixed at G in a carriage H, sliding horizontally in the frame of the machine. At *e* are three screws of the same size as the screw B of the boring-machine, each furnished with a similar ring at the end. This ring enters the impression made by the boring-machine, so as to fix the block in its proper position when the screw is turned. This forces the other end of the block against the cross-bar of the carriage, which has three steel circles fixed to it opposite the end of the screw *e*. Each of these rings includes two smaller rings with a sharp edge, and the pressure of the screw *e* forces the block against these rings, and prints their figure in the wood. By this contrivance the block is held quite fast in the carriage while being mortised. Behind the carriage is a large double-wormed screw R, and this is received through a nut turning round in a fixed collar, supported by a bar across the frame. To this nut two wheels *g h* are fixed: the former is a large ratchet-wheel; the latter a cog-wheel with a smaller one gearing with it, and fixed to the end of a long axis *k* furnished with a winch *r*. When this is turned round by hand, the nut of the screw is also turned, and the carriage is moved slowly backwards or forwards. In this way the carriage is adjusted to the proper point for beginning the work. The gradual advance of the block to each cut of the chisel is produced by turning the ratchet-wheel *g* by the following contrivance. The axis D has an eccentric circle I fixed upon it, which as it revolves acts upon a roller K fixed in one arm of a bent lever; the other end of this arm has a rod *m* jointed to it, with a tooth in the middle, which engages the teeth of the ratchet-wheel, and turns it round, a tooth at a time, as the rod moves backwards and forwards. The extreme end of this rod rests upon a lever *n* (except when being drawn over the sloping side of the tooth of the ratchet-wheel), the centre of which is a pin fixed in the vertical column of the frame. It is held up by a second lever, *o*, supported on a cock screwed on the frame. The opposite end of this lever is made so heavy that its weight is sufficient to raise up *n* and *m*, so that the tooth of the latter will be too high to intercept the teeth of the ratchet-wheel in its motion. The heavy end of the lever is kept up by a piece of metal fastened to the side of the carriage, at *p*, by screws passing through oblong grooves, so that it can be attached at any part along the length of the carriage. By this means, when the carriage has advanced as far as required, the loaded end of the lever *o* falls off the piece *p*, and disengages the rod *m* from the ratchet-wheel. The fly-wheel and drum which turn the machine are fitted on a cylindrical part of the axis, so as to move freely thereon when it is not required to work the machine. A conical wheel s, with a hollow axis or tube centre-piece, is fitted upon the axis D so as to slide freely endwise, but is confined to revolve at the same time by fillets inserted in it. The end of the tube of the wheel S is formed into a circular groove, which is embraced by a forked lever L, centred in the opposite side of the frame. By moving the end of L towards the fly-wheel, the conical wheel S is thrust forward, and jammed into the inside of the drum A. This exactly fits the wheel, and the friction caused by the contact of the two conical surfaces is sufficient to work the machine. But when the lever L is pulled away from the fly-wheel, the conical wheel is drawn out from the rigger, and the fly-wheel detached from the axis, so as to revolve upon it freely without turning it.

In using this machine the block is applied with its screw mark to the end of one of the screws *e*. If a double block is to be mortised, as in Fig. 151, the centre screw is used; but if 2 single sheaves are to be fixed in, the 2 outer screws are used. By screwing it tight, the block is fixed between the double circle points before mentioned. To guide the block to its proper position, so that the hole bored for the commencement of the sheave hole shall be vertical, the block being fixed, the handle *r* is turned till the hole is brought beneath the sliding frame. The chisels are now adjusted. These are long square bars of steel TT, fastened to the frame by a clamp. The back of each chisel has a small piece of steel attached for thrusting out the chips which it cuts, to prevent the hole from being clogged up. It has also two small cutters or *scribers*, fixed perpendicular to its edge, and projecting rather before it, so that in the descent of the chisel, two small clefts are cut or scribed, which include the width of the chip to be cut out by the chisel in the succeeding stroke. By this means the mortice has its sides perfectly smooth. The back of the chisel is rounded to conform to the hole bored in the boring machine.

The clamp to which the chisels are attached passes behind the cross-bar of the frame, and the chisels being put exactly over the holes which are to become

sheave-holes, are screwed fast by means of clamps. The machine is now put in motion by depressing the handle P, which is at the end of a lever, the fulcrum of which is a pin fixed in the column of the frame at *s*, and a short arm gives action to the end of the lever L, so as to put the machine in motion. At the first descent of the chisels, they cut down through the whole depth of the holes previously bored, so as to give them a flat side when they rise up. The eccentric circle I, moving the bent lever and rod *m*, turns the ratchet wheel round on both and advances the block through a small space in the direction of the fly-wheel, so that the chisels in descending cut a fresh space, and in ascending the block advances. In this way the sheave-holes are rapidily cut, each chisel making from 110 to 150 strokes per minute, and cutting at every stroke a chip as thick as pasteboard with the utmost precision. When it is completed, the loaded end of the lever *o* drops off the piece *p* previously adjusted, and raises the rod *m*, so that the further advance of the block is prevented. The attendant then raises the handle P, which stops the machine. The finished block is now removed and a fresh one put in: the handle *r* is screwed back to bring the block to the proper point, and the machine is set in motion as before. By an adjustment of the cross bar in the back of the carriage, the mortising machine is adapted to blocks of different sizes, and the frame E may have any number of chisels fixed to it corresponding to the number of mortices required to be cut.

7. The corners of the block are next cut off by means of the *corner saw*, Fig. 152, which consists of a mandrel mounted in a frame A, carrying a circular saw L on its extremity. The frame of this mandrel

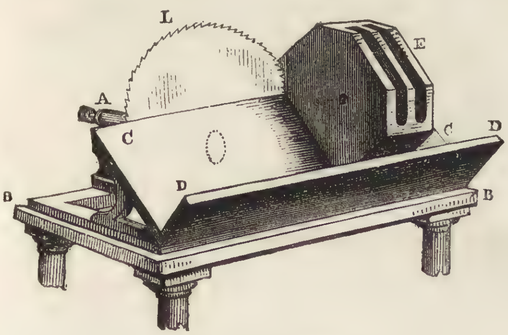


Fig. 152. THE CORNER SAW

is screwed down upon the frame BB, which is supported by four columns. CC DD is an inclined bench or trough, in which a block, as E, is laid, being supported on its edge by the plane C, and its end kept up to its position by the other part of the bench D. By sliding the block along this bench it is applied to the saw, which cuts off its four angles in succession, by applying its different sides to the trough. In the figure, two of the angles have been cut off and the third is just marked by the saw. By laying pieces of wood of different thickness against the plane D, so as to fill it up, the block is kept nearer to or further from the saw, and in this way different sizes of blocks can be cut.

8. The blocks thus prepared have their outside surface formed to their true figure by means of the *shaping machine*, Fig. 153, the principal part of which is the chuck which holds the blocks. This consists of two equal wheels, A, B, mounted on the same axis, A being firmly fixed, while B slides upon it so as to render the space between them greater or less, as may be required for blocks of different lengths. This is effected by means of five bolts and nuts, the heads of the nuts being shown at *x*. Both wheels are divided into 10 equal parts. At each of these on A, a short axis or mandrel is fitted through a projecting part of the rim of the wheel. On the outside of the wheel each of these mandrels has a small wheel *a* fixed upon its end. On the ends in the inside of the wheel the mandrels have each a short cross-bar fixed, sufficiently long to contain two steel rings, which are exactly the same size and distance apart as those in the morticing machine, which support the block. The wheel B has at each point opposite the mandrils *a*, a screw centre similar to the back centre of a lathe, but furnished at its point with a steel ring of the same size as that at the end of the screw of the boring machine. The blocks are held in between the wheels by putting the double point at one end of each block, against the double rings at the end of one of the mandrels; and then, screwing the screw in the other wheel tight up, the block is confined between them. In this manner the chuck being filled with 10 blocks, if they are turned round rapidly and a chisel or gouge be fixed for them to cut against, each will be formed to a segment of the circle in which they move. This gouge is supported in a frame moving on a fixed rest D, which is curved to a circle whose centre is in the centre of the chuck. It is confined to move on this arch by a curved radial bar E, fitted to centre on the floor beneath the machine at one end, and having the other attached to the frame F which supports the tool. This frame contains a slider *f* moving in a groove, and at the end carrying the tool *g* in a holder. The slider has an axis or spindle fitted perpendicularly in it at *h*. On the lower end of this is a roller, which applies itself against a curved piece of metal *i*, called a *shape*, fixed upon the framing. The roller is kept in contact with the shape by a lever centered at *k* on the frame F, and connected by a short coupling iron with the slider *f*; so that when its handle *l* is pressed towards the machine, the roller is kept up to the shape. By means of a handle G jointed to the frame F, which carries the tool and all its apparatus, this frame can be moved along the rest D, being guided by the radial bar E in its motion. Now if the other handle *l* be at the same time pushed forward, the roller applies itself to the shape, and the gouge describes the same curvature as the shape. Below the first shape is a second *m*, and by a simple movement the roller can be depressed so as to roll in the second shape, and give the curvature of it to the tool instead of the upper one.

Supposing the 10 blocks to be fixed as just described, the frame F of the gouge is turned to one end of the rest D, and the chuck put in rapid motion, by a band round a pulley H, on its axis. The attendant, with the handle G in his right hand and *l* in his left, sweeps the frame along its rest by the handle G, while he keeps the roller in contact with the shape, by pressing the lever *l* towards the machine. In this movement, the gouge cuts to their proper curvature the faces of all the 10 blocks which are farthest from the centre. When the frame has slowly traversed the whole length of its sweep, the outside faces of all the blocks are finished, and the machine is stopped by casting its movement off from the mill. But as it preserves a considerable velocity, this is checked by a steel spring at I, fixed at one end to the frame, and extending round a wheel fixed on the pulley H. The other end of this spring has a handle, which being pressed down, the curved part of the spring encloses the wheel and acts as a gripe. When the motion ceases, the blocks are all turned one quarter round on the small mandrels *a*, by an endless screw on each of the wheels *a*. These screws are cut in the ends of as many spindles *d*, pointing towards the centre of the chuck. At the ends of those nearest the centre, each spindle has a small bevelled wheel *c* fixed upon it. There is also a large bevelled wheel K fitted upon the axis, between the wheel A and the pulley H, so as to slip freely round upon the axis, and when it is turned round, it will evidently turn all

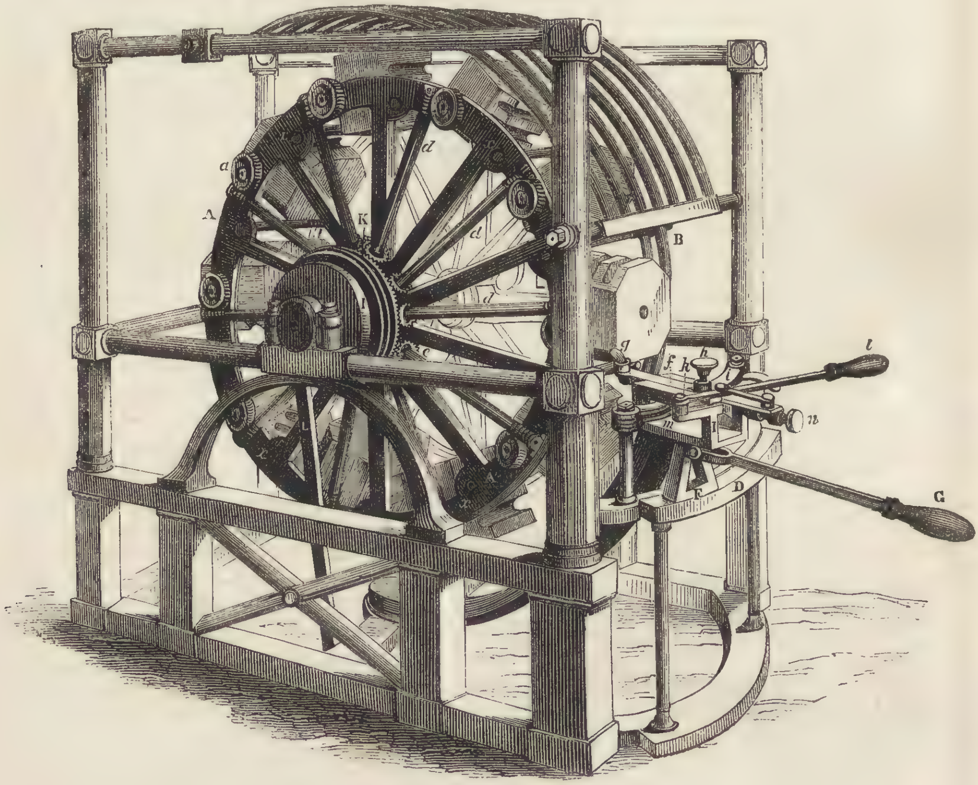


Fig. 153. THE SHAPING MACHINE

the wheels, spindles, screws, and mandrels at once, and thus turn all the blocks so as to bring another face outwards. While the chucks are turned round, the wheel is held fast, and the wheel K is stopped by a catch L, moving in a joint fixed on the ground. This wheel being detained, the attendant takes hold of the chuck by its rim and turns it round 4 times, and the bevelled and other wheels are so proportioned that those 4 times will make the blocks revolve exactly one quarter on their separate axes, so as to bring another side of each block outside. The machine is then set in motion as before, and the work is alternately stopped and carried on until all four sides are finished, the upper shape being employed to cut the third side in the same manner as the first, and for the second and fourth sides, the lower shape is used. By means of a screw *m*, the socket supporting the axis of the roller *h* can be moved along the slider, the effect of which is to project the tool *g* more or less beyond the shape, as may be required to cut larger or smaller blocks. The same shapes will serve for several different sizes.

This machine is surrounded by an iron cage (a portion of which is shown in Fig. 153), for the purpose of defending the workmen, lest the blocks which are revolving with great velocity should be loosened by the action of the tool, and fly out by their centrifugal force.

9. As the blocks come from the shaping engine, they are taken to the *scoring engine*, which forms the groove round their longest diameters for the reception of their ropes or straps. This engine receives two blocks A, B, Fig. 154, each held between two small pillars, *a* fixed in a strong plate D, and pressed against the pillars by a screw *b*, which acts on a clamp *d*. Over the blocks a pair of circular planes or cutters, E E, are fixed on one spindle, which is turned by a pulley in the middle. This spindle is fitted in a frame F F, moving in centres at *e e*, so as to rise and fall when moved by a handle *f*. This brings the cutters down upon the blocks, and the depth to which they can cut is regulated by a curved shape *g*, fixed by screws upon the plate D between the blocks. Upon this rests a curved piece of metal,

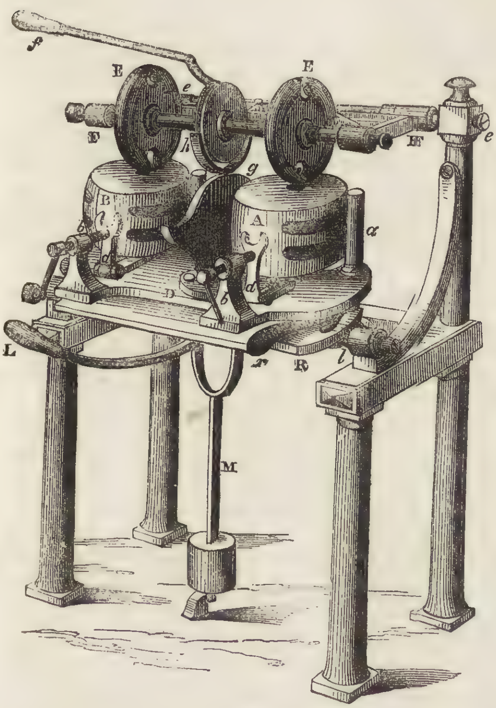


Fig. 154. THE SCORING ENGINE.

h, fixed to the frame F, and enclosing, but not touching the pulley. To admit the cutters to traverse the whole length of the blocks, the plate *d* is sustained between the points of two centres, which are furnished with screws at *l*. On depressing the handle L, the frame is inclined. At M a lever, weighted at the end, counterbalances the weight of the blocks and plate D, all which are above the centre on which they move. The frame F has also a counterpoise to balance the cutters, &c. The cutters E are circular wheels of brass with round edges; each has two notches in its circumference at opposite sides, and, in these notches, chisels, fixed by screws, project beyond the rim of the wheel.

In using this machine, the block is pressed between the two pins, *a*, and the clamp *d* is screwed up against it. This clamp has two claws, each furnished with a ring, which enters the double points before mentioned in the end of the block. The blocks being properly mounted, the attendant presses the cutters E E by means of the handle *f* down upon the blocks, depressing them between their pins until their descent is stopped by the piece *h* resting on the shape *g*. He then turns the screws *b b*, to fix the blocks tight, and the cutters being put in motion will cut the scores, which, by the adjustment previously made, will be of no depth at the pin-hole; but, by depressing the handle L so as to incline the blocks, and keeping the cutters down upon their shape *g* by the handle *f*, they will cut any depth towards the ends of the blocks which the shape *g* admits. In this way one quarter of the score is formed; the other is done by turning both blocks together half round, by the following contrivance:—The centres *l* are not fitted into the plate D, but into a frame at R beneath the plate, which is connected with it by a centre pin, exactly midway between the two blocks, A, B. A spring catch, the end of which is seen at *r*, confines them together; when this catch is pressed back, the plate D can be turned about upon its centre pin so as to change the blocks end for end, and bring the unscored quarters or those over the clamps beneath the cutters; the workman, taking the handles *f* and L one in each hand, and pressing them down, cuts out the second quarter. This might have been done by simply lifting up the handle L, in which case, however, the cutter would have struck against the grain of the wood, but by reversing the blocks, it always cuts clean and smooth in the direction of the grain. The third and fourth quarters of the score are cut by turning the other sides of the blocks upwards and repeating the above operations. The shape *g* can be shifted for different sizes and curves of blocks.

As some of the shaping machines cut the wood without reference to the grain, roughnesses are left which require to be smoothed down. This is done by hand, and a smooth polished surface is produced without removing any of the wood.

10. For making the sheaves, the first process is cutting pieces or flakes off the end of the trees of lignum vitæ, of the proper thickness to form the sheaves. This is done by means of three *converting machines*, one with a reciprocating saw and the others with circular saws. The flakes are made circular, and their centres pierced by means of a *crown saw* which has a centrebit in the axis. The flake being fixed before this saw, it quickly cuts out a circle, and, at the same time, forms a centre hole.

11. *The coaking engine* is a most ingenious machine; it forms a cavity in the centre of the sheave for the reception of the coak or bush of bell-metal, which forms a socket for the centre pin. This cavity is in the form of three small semicircles, arranged at almost equal intervals round the hole formed by the last machine.

12. A *drilling machine* for perforating the three semicircular projections of the coaks, for the reception of short wire pins or rivets, which are rivetted down at the same time with the rest of the coak.

13. *Riveting hammers;* two small tilt hammers for firmly riveting the coaks after they are put into their places.

14. The centre holes through the coaks are next broached out to a true cylinder by means of the *broaching engine.*

15. The faces of the sheaves are lastly turned to a flat surface in a *facing lathe,* which also forms the groove in their periphery for receiving the rope. This completes the machine for making the sheaves.

The iron pin or axis of the block is forged by two smiths between two swages, or tools each having a semicircular cavity in it, so that the two when put together form a cylinder. The heated iron being laid in one of these, the iron is put over it and beaten with a hammer into a cylindrical form. One end of the pin is left square for a short length. In this state the pins are turned by a slide rest in the pin-turning lathe; this covers them with spiral scratches from the scorings of the tool, and they are afterwards polished and made perfect in the *polishing engine,* in which the pin is fixed in the lower end of a vertical revolving axis, and forced down into a sort of die immersed in oil holding three pieces of hard steel, between which the pin is pressed as it turns, and this perfects the polish.

Blocks, from 4 to 7 inches in length, are generally fitted with wooden pins, which are turned in a lathe called a *whisket.*

There are also two machines for making dead-eyes from 5 to 9 inches, and also from 10 to 19 inches in diameter.

There is also a large *boring* machine, for making the largest sizes of blocks, called *made* blocks, some of which are as much as 4½ feet in length, with four sheaves.

The number of machines employed in making the blocks is forty-four. These are divided into three sets, so that three sets of blocks of different sizes may be proceeding in all their stages at the same time, although in some of these stages one machine operates at the same time upon two, or even ten blocks.

The different blocks made by these machines are as follows:—

Thick blocks, four varieties—single sheaves, double sheaves, treble, and fourfold. The sizes of each variety are from 4 inches to 28 inches in length; but only the first three varieties are made wholly by the machine, the fourfold being chiefly made by hand; but their sheaves and pins are entirely formed by the machines.

These make about	72	sizes
Thin blocks are the same as the above, but with narrow sheaves: these are from 6 to 26 inches in length . .	48	„
Clue-garnet and clue-line blocks, of peculiar construction, introduced by the inventor of this machinery .	10	„
Sister blocks	20	„
Top-sail sheet blocks	20	„
Fiddle or viol blocks	24	„
Jack blocks	20	„
	214	

The number of block-shells, of different sizes, made by each set of machines in a day, is thus stated:—

The first set of machines makes blocks, from 4 to 7 inches in length, at the rate of 700 per day. These have wooden pins.

The second set makes blocks, from 8 to 10 inches in length, with iron pins, at the rate of 520 per day.

The third set makes blocks, from 11 to 18 inches in length, with iron pins, at the rate of 200 per day. Total, 1,420 per day.

BLOOD is the general circulating fluid of the animal body, the source of nutriment and growth, and the material from which all the secretions are derived. In all vertebrated animals it is of two kinds, the *arterial,* which is of a bright red colour, and the *venous,* which is blackish purple. The temperature of the blood is connected with the degree of activity of the respiratory process. In man this temperature is about 98°. The density of blood varies from 1.053 to 1.057. It has a slimy feel, an alkaline reaction, and when recent, a peculiar odour. By the addition of sulphuric acid to old blood, an odour is developed, which is said to be characteristic of the animal from which it was obtained. Soon after blood has been drawn from its vessels, it gelatinizes or coagulates, and the jelly or coagulum separates into two parts, a liquid *serum,* and a soft clot or *crassamentum.* During coagulation, the colouring matter, called *hematosine,* which is diffused through the crassamentum, so as to give it a uniform red colour, is thrown off. This red pigment has many of the characters of a dye stuff, and contains oxide of iron.

The serum, or fluid part of blood, is an alkaline solution of albumen, containing various soluble salts. The clot is a mechanical mixture of fibrine and colouring matter, swollen and distended with serum. Blood is sometimes used in the arts for the sake of its albumen [See ALBUMEN]: but its use is much less at present than formerly. The chief use of blood is as a manure. It is seldom applied directly to the land, but is made up into a compost by mixing about 50 gallons of blood with a quarter of peat ashes and charcoal powder, and allowing the mixture to stand for a year or two. On light soils this compost raises excellent turnips, when applied alone at the rate of 48 bushels per imperial acre; or of 2 quarters, with 12 tons of farm-yard dung. As a top dressing to young wheat, 20 or 30 bushels an acre greatly increase the crop. In Northamptonshire, where this manure is much used, the blood is contracted for at the rate of 3*d.* a gallon. In some countries the blood is dried, and applied in the state of powder as a top dressing to the growing crops. In this state it is sold in Paris at about 8*s.* a cwt.[1]

BLOWPIPE, an instrument for directing a small jet of air laterally into the flame of a candle or lamp, whereby a portion of the flame is formed into a long slender cone in the direction of the jet, the heat of which increases towards the end of the cone, and at the point is most intense. In this way a common flame is converted into a species of furnace, capable

(1) "Johnston's Elements of Agricultural Chemistry:" 1848.

of fusing or raising to a high degree of temperature any substance minute enough to be involved by the flame. The blowpipe is in common use in the Arts; it is used in soldering by the jeweller, goldsmith, and those who fabricate small objects in metal; by the glass-blower in making instruments and toys of glass; by the enameller, and others It is also an invaluable instrument in the hands of the analytical chemist, superseding to a great extent the large furnaces and cumbrous apparatus of former times.

The common blowpipe, Fig. 155, is a conical tube

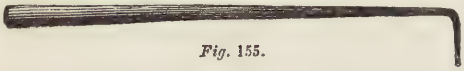


Fig. 155.

or pipe, generally of brass, about 8 inches long, and a quarter of an inch diameter at the top, with a curvature near the lower end, whence it tapers off to a point, which has a very small perforation for the escape of the jet. This is the simplest and cheapest form, and is used at the present day by artisans. But as in using this tube the moisture of the breath is apt to condense within it, a bulb *b* is sometimes made near the small end of the pipe, as in Fig. 156, and to render

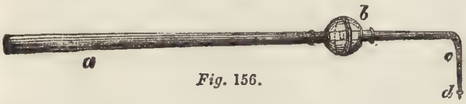


Fig. 156.

it more portable, it is divided through the middle, and the two parts screw together, when used. This form was improved by Bergman, and afterwards by Gahn, whose blowpipe consists of four pieces, *a, b, c, d,* Fig. 157.

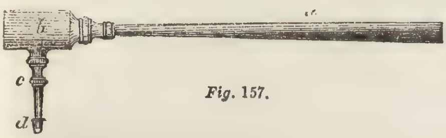


Fig. 157.

The small jet *d* is fitted by grinding to the extremity of the beak *c*, and several of these jets are provided with holes of different diameters, to be changed according as a larger and more moderate, or a smaller and more intense flame is required. The chamber *b*, for condensing the moisture, is a cylinder 1 inch long, and half-an-inch diameter. The varieties of blowpipe are very numerous. Wollaston's is the most portable. Figs. 158, 159, 160, show its form, the number of pieces composing it, and the method of putting the parts together, either for use or for travelling; *a, b, c,* Fig. 158, show the three pieces put together for use.

Fig. 158.

The point of *b* is closed, but just above the point, at the side of the tube, is a small opening *b*, Fig. 159, which emits the air into the beak *c*, Fig. 158, when brought into its proper situation on the tube. Fig. 160 represents the blowpipe packed up into the space of a pencil-case. "If we

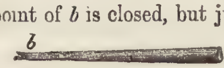


Fig. 159.

Fig. 160.

add to this a slip of platinum foil two or three inches long, to hold the object of experiment to the flame, and a small piece of borax to serve as a flux, we are furnished at once with a sufficient laboratory for a great variety of experiments; for the candle and charcoal may be found in most places." Fig. 161

Fig. 161.

is Pepys's blowpipe, in which the vapour is condensed in a flat cylindrical box, which also answers the purpose of holding additional caps for the nozzle. Fig. 162 is Dr. Black's blowpipe. It is of tinned iron; the small pipe *a* is of brass, and has two or three caps that fit on tight, each cap being pierced with a hole of a different diameter.

Fig. 162.

To use the blowpipe properly, requires some art, for while the air is inspired through the nostrils, that which is contained in the mouth must be forced out through the tube by the compression of the cheeks, so as to keep up a continued stream for a quarter of an hour if necessary. To acquire this art, Mr. Griffin advises the learner to begin by practising breathing through the nostrils with the mouth closed; then "let the learner transfer the air into his mouth, allowing his cheeks to distend as the air arrives through the posterior nostrils, and then let him make two or three moderate inspirations and expirations by the nostrils without opening the lips or suffering the air to escape from the mouth." Then "let him introduce between his lips, the mouthpiece of a blowpipe, having a small aperture, and then, having filled his mouth with air, let him allow the same to be gently expelled through the tube by the action of the muscles of the cheeks, at the same time that he continues breathing, without interruption, through the nostrils. This is done by applying the tongue to the roof of the mouth, so as to interrupt the communication between the anterior part of the mouth, and the passage to the nostrils. When the mouth begins to be empty, it is replenished by the lungs in an instant, while the tongue is withdrawn from the roof of the mouth, and replaced again in the same manner as in pronouncing the monosyllable *tut*. After practising this for a few days, the muscles employed will be accustomed to this new exertion, and unless the flame be urged too impetuously, a continued current may be produced without any extraordinary exhaustion."

For the information which is to be acquired from the use of the blowpipe, we must refer to special treatises on the subject. One of the best of these is by Berzelius, a translation of which, from the French edition, was published by Mr. Children, in 1822. An American edition by Mr. Whitney has been published more recently. Mr. Griffin's "Practical Treatise on the use of the Blowpipe in Chemical and Mineral Analysis," Glasgow, 1827, is an admirable little work, a new edition of which, would be of great

assistance to the student. But the most elaborate Treatise on the Blowpipe is that by Professor Plattner, of Freiberg, entitled "Die Probirkunst mit dem Löthrohre," Leipzig, 1835. There is a translation of this work by Dr. Muspratt.

The table blowpipe and other forms of compound blowpipe will be described under ENAMEL, GLASS, &c.

BLUBBER, a deposit between the skin and the muscles of the members of the order Cetacea, and most abundant in the Greenland whale, its thickness being from 8 to 10 or 20 inches. The uses of this layer are to render the huge body of these animals specifically lighter than the surrounding fluid; to assist in the preservation of the vital heat; and to afford protection to the internal organs against the effects of the enormous pressure to which these animals are subject in the depths of the ocean. The blubber of a full-grown whale is said to yield as much as 100 tuns of oil. It was formerly the custom, when whales were numerous, and the fishing comparatively easy, to boil the blubber on the spot, and to bring home the oil in casks. As the fishery became more difficult, and the whales had to be pursued further into the open sea, it was found more economical to bring home the blubber or *finks*, as it is called, cut in small pieces, and packed in casks. When it arrives in England, it is putrid, and in order to get rid of the rancid smell and taste, and to purify the oil, the following method is adopted. The casks are emptied into a large back, or receiver, containing about 20 tuns: from thence the fluid parts are suffered immediately to strain through a semi-circular wire grating in the side of the back, close to the bottom. This grating is about 4 feet wide, and 2 feet high, receding in a convex form into the back, and the wires sufficiently close to prevent the finks from passing through. The oil, as it drains through this grate, is conducted by a copper tube, 4 inches in diameter, into another back, containing about the same quantity. When this is full, it is left about two hours to settle, after which it is conducted by means of a sluice into a copper of the capacity of about 14 tuns, and is heated by a fire. The oil must be stirred in the copper until it has attained the temperature of 225°, which will destroy the rancidity of the smell, and also precipitate the grosser animal matters. As soon as this temperature is attained, the fire is removed, and about half a tun of cold water is pumped upon the surface of the oil in order to cool the bottom of the copper, and prevent the solid parts from adhering to the sides. The oil is then left to cool an hour, and is then drawn off into coolers, and when perfectly cold, is stored in casks. In this state it is fine, and fit for immediate use. [See OIL.]

BOAT. A small vessel, generally without a deck, managed by sails or oars, or drawn by horses upon canals. The form, equipment, and names of boats, vary according to the purpose for which they are intended; hence they are made slight or strong, sharp or flat-bottomed, open or decked, plain or ornamented, as they are designed for swiftness or burden, for deep or shallow water, for sailing in a harbour or a sea, and for convenience or pleasure. Boats are a necessary appendage to a ship: ships of the line have usually six boats, but the number decreases with the rate of the ship. The largest is called the *long-boat* or *launch*, and its chief use is to convey heavy stores to the ship. It is generally furnished with a mast and sails, and is sometimes decked, armed and equipped. Next in size to this is the *barge*, and its chief use is to convey the principal officers to or from the ship. It is of slender construction and of small breadth, and never rows less than ten oars. The *pinnace* is similar to the barge, but smaller: it never rows above eight oars, and is used by lieutenants in going ashore or coming off to the ship. *Cutters* are broader, deeper and shorter than the former; they are employed on most occasions for going ashore, carrying stores, provisions, boarding ships at sea, &c. The *jolly-boat* is the smallest boat used in any of the ships of the navy. In an East Indiaman there are four boats; the *long-boat* for conveying stores and goods to and from the ship; the *cutter* for going ashore; the *jolly-boat* and the *yawl* for occasional use.

At the close of the last century it was proposed by the Rev. Mr. Bremmer, that empty casks should be firmly fixed in ship's boats, so as to convert them into *life-boats*, or such as are incapable of sinking when filled with water. Upon making trial of the plan suggested, it was found to answer perfectly. A man-of-war's jolly-boat, Fig. 163, was thus rendered buoyant,

Fig. 163. BREMMER'S LIFE-BOAT.

and to keep it upright in order to launch it from a flat shore and to resist upsetting, it was furnished with billage boards of equal depth with the keel. When a large piece of iron or lead was let into or fastened to the keel, the boat when accidentally upset immediately regained its original posture. A stout projecting rope, with swellings on it to increase its elasticity, surrounded the gunwale, and served as a fender, and prevented the boat from being staved in, in lowering it down, or when driven in contact with the vessel it might be going to relieve. When this boat was filled with water and contained five persons, such was it buoyancy that it was kept above the water's edge, and could be rowed with the greatest ease, and was capable of performing any service required.

About the year 1785, Mr. Lukin took out a

patent for a life-boat with projecting gunwales and hollow cases or double sides under them, as well as air-tight lockers or inclosures under the thwarts or seats for the rowers. These arrangements greatly increased the buoyancy, and prevented rolling. The great defect of this boat was its liability to be staved in. This led to the invention of a life-boat by Mr. Greathead of South Shields, in 1789, which was so successful in its operation, that before the year 1804, it had saved nearly 300 lives from vessels wrecked near the mouth of the Tynemouth haven. The inventor received a gold medal and fifty guineas from the Society of Arts, and a parliamentary reward of 1,200*l.*, besides rewards from the Trinity House and Lloyd's Coffee-house. The success of this boat led to the establishment of stations at most of our ports, where life-boats, manned by active persons, were always kept ready to put to sea for the relief of seamen in distress. This boat, Fig. 164, was 30 feet

Fig. 164. GREATHEAD'S LIFE-BOAT.

in length and 10 feet in breadth, its greatest depth being about 3 feet, besides a general convexity which nearly doubled the depth as reckoned from the ends; the convexity below being intended to give it a greater facility of turning and a greater power of mounting on the waves without submersion of the bow, which would increase the resistance although it would not sink the boat: the breadth was also continued further than usual fore and aft, in order to contribute to the same effect. The gunwale projected some inches, and the sides were cased and lined with cork secured by plates of copper and fastened with copper nails, which gave the boat so much buoyancy that it would float and be serviceable, although so much damaged as to be almost in pieces; but the cork by its softness and elasticity was well calculated to prevent such an accident. The whole quantity of cork was 7 cwt. : on the outside it was 4 inches thick, and extended the whole length of the shear or side of the boat: on the inside it was thicker. Ten short oars of fir were fixed on pins to the gunwales, and a longer oar for steering was fixed at each end, both ends of the boat being alike. The boat was painted white in order to be more conspicuous, and it was entrusted to an experienced man acquainted with the times and direction of tides and currents, and he was recommended to keep the boat with her head to the waves as much as possible, giving her an increased motion as he neared a wave. Much care is required on approaching the ship in distress, in consequence of the reflux of the waves, and it is in general better to get to the ship on the lee side. The rowers were recommended to exercise themselves in the use of this boat, and to obey strictly the person commanding. A carriage moving on four small wheels was provided for conveying this boat over land when required, but as this plan was not found very convenient, the following was adopted:—Two wheels 9 feet in diameter are connected by an arched axle, to which is fixed a strong pole of considerable length to serve as a lever: the wheels are so far apart that the boat can stand between them with the arched axle over its centre. When the pole is horizontal, the arch rises above the boat, but when the pole is erected perpendicularly, the arch touches the boat. In order to move the boat, the arched axle is brought over its centre and the pole set upright: two chains fastened to the arch are then hooked on to two eyebolts fixed in the inside of the boat: the pole is then lowered, the arch rises and brings up the boat with it. In this way it can be moved rapidly on land, and can be launched with great facility.

In the year 1807, the gold medal of the Society of Arts was awarded to Mr. Christopher Wilson for a life-boat with air gunwales, which is said to be lighter and more manageable than Greathead's boat. One advantage of this boat was that the hollow outriggers or air vessels were distinct from each other, so that if one of them were beaten in by striking on a rock, the rest would still be serviceable.

Since the extensive application of India rubber, and more recently of gutta percha, to the purposes of the useful arts, these substances have been employed with much success in the construction of life boats. Ships have also been furnished with various kinds of life buoys. [See Buoy.] Cork mattrasses have also been partially introduced on board ship, but as they afford facilities to the sailors to desert, they have been discontinued.

BOBBIN-NET. [See Lace.]

BOILER. [See Steam-Engine.]

BOILING. [See Ebullition.]

BOLE. An earthy mineral forming one of the hydrous silicates of alumina, and resembling Soapstone. Specific gravity, 1.4 to 2. It occurs in masses in Armenia, Saxony, Italy, France, Ireland, Scotland, various parts of South America, &c. It is friable, has a greasy feel, and is of various colours, as yellow, brown, red, and black. When put into water it readily absorbs it, emitting bubbles of air, and falling to pieces. Bole found in the island of Lemnos, is called Lemnian earth, and was formerly employed as an astringent, absorbent, and tonic medicine, but this and the other varieties of bole have fallen into merited neglect as medicines. Any tonic effect they might have had was due to oxide of iron, which is

now given in a purer form. Armenian bole is still in demand in India for this purpose, and boles in general still enter into veterinary medicines in Europe. Armenian bole is of a fine bright red, and is much used as a tooth-powder. Humboldt, in describing the habits of some savage nations of South America, says that they allay the pains of hunger by eating boles. Cakes made of these earths, and called *tanaampo*, are also in request among the natives of Java, when they wish to become thin. A coarse red bole calcined and levigated is sold in Germany as a pigment, under the name of Berlin and English Red.

BOMBAZINE (from the Greek βόμβυξ, a silk-worm). A fabric of worsted and silk, the warp being of silk, and the weft or shoot of worsted.

BONE is formed of a dense cellular tissue of membranous matter, rendered stiff and rigid by insoluble earthy salts, of which phosphate of lime is the most abundant. The proportions of earthy and animal matter vary greatly with the kind of bone, and with the age of the individual, the bones of an adult been richer in earthy salts than those of an infant. The following comparative analysis of human and ox-bones will show the nature and amount of the constituents:—

	Human bones.	Ox-bones.
Animal matter soluble by boiling	32.17	33.30
Vascular substance	1.13	
Phosphate of lime	53.04	57.35
Carbonate of lime	11.30	3.85
Phosphate of magnesia . . .	1.16	2.05
Soda and a little common salt .	1.20	3.45
	100.00	100.00

The teeth have a similar composition, but contain less animal matter, so that their texture is more solid and compact than bones. The enamel does not contain more than 2 or 3 per cent. of animal matter.

If bone be digested in very dilute muriatic acid, a moderate degree of effervescence will take place in consequence of the presence of carbonate of lime. In some days all effervescence and chemical action will cease, and that which remains undissolved will still represent the size and form of the original bone, but its appearance is changed, for it is semitransparent, cellular, soft, flexible, and to a certain extent elastic. If this be washed and boiled in water, a portion of it will dissolve, and the solution, boiled down to the proper consistence, will become viscid and gelatinous on cooling, and will dry into a hard glue. If again dissolved in water it will become curdy, and give a grey precipitate with solution of nutgalls, and exhibit all the properties of gelatine. The remaining portion is insoluble in water; it becomes hard and somewhat brittle in drying, and burns like horn. Dissolved in caustic fixed alkali, it forms a soapy liquor, and exhibits all the other properties of albumen or membrane. The acid solution in which the bone was steeped will on the addition of caustic ammonia give an abundant precipitate of phosphate of lime, and a much smaller precipitate of carbonate of lime on the addition of carbonate of ammonia.

Fat, although usually present in bone, is not an essential part thereof. The horn of the stag and of other animals of the same kind is entirely free from fat; hence, hartshorn jelly, made by boiling the shavings of stags'-horn in water, is often recommended to persons of very weak digestion in preference to other animal jellies, as being absolutely free from oil; for although hard fat will not combine with jelly, yet the softer oily fats will do so in small proportions.

All animals that eat flesh, also eat bones if of a size to be easily crushed and masticated. The richness of meat soups is increased by boiling the bones with the meat, but in this way only a small portion of the food contained in bones is made available; a part of the gelatine is with difficulty, and the membranous part not at all, soluble in common boiling water. Much of the fat locked up in the cells of the bone cannot escape unless the cells be broken into. The solid part of the long bones contains, however, very little soluble matter; but their enlarged extremities and articulating surfaces afford the chief supply of nutritive matter. These parts should be sawed off, and the rest broken to pieces. The bones of young animals thus treated will in the course of two or three hours yield most of their soluble matter to boiling water; but in the bones of the older animals the gelatine seems to be in a state of condensation approaching that in which it exists in the skin, and therefore requires the long-continued action of boiling water to separate it. By means of a *digester*, or boiler with a steam-tight cover and safety valve, the temperature of the water may be safely raised to 270° or 280°, but at a less heat than this the condensed gelatine and membranous portion of the bone become dissolved if previously reduced to small pieces. The insoluble residue will be found a friable, crumbling mass, with scarcely any remains of animal matter. Bone soups are prepared in this way at the hospitals and military head-quarters in France, and it has been proposed to make a collection of dry bones a part of the provisions of a garrison in case of siege. If formed into stacks covered with thatch, they would be imperishable, and not be exposed to the attacks of mice and rats. The only objection to bone soup is that it sometimes has a burnt flavour, but it has been proposed to get rid of this by first digesting the bones in dilute muriatic acid in a stone trough until the earthy matter is dissolved out; then wash the membranous portion now left in an abundance of water; and lastly, sprinkle it with a little soda to get rid of all traces of the acid. By exposure to the air the membranes will dry to a horny texture without any fear of decomposition; and this can be more easily converted into a palatable food than by cooking the entire bone.

In Norway and Sweden, in times of scarcity, fish-bones, such as those of the mackerel, browned on a gridiron until they become friable, and, eaten with pepper and salt, form a palatable food.

The spines in the back fin and tail of some fishes are used in some parts of the world for pointing arrows. The serrated teeth of sharks are also used as offensive weapons. Fish-hooks are made of bone by some nations; and bones of fine texture, especially the teeth or tusks of the hippopotamus, elephant, walrus, and narwhal, are well adapted for carving, sculpturing, and turning. Ivory is also used for inlaying. Common bone furnishes excellent handles for small brushes, and other articles. In making utensils of bone, the compact cylindrical ones are preferred, as being stronger, and admitting of a more uniform and higher polish. The scrapings, shavings, or saw-dust of bone fetch a good price in the market, as they are much used by pastry-cooks and others as a material for jelly, which they readily give out to boiling water. Bone shavings are also used in case-hardening small articles of steel.

Bones also form a valuable manure, and for this purpose a supply is often obtained from many of our limestones, which contain abundant remains of corals and other animals. In the Saurian remains that abound in lias limestone there is a large store of phosphate of lime, and many of the corallines contain as much of this valuable substance as the bones of mammalia. A large proportion of the bones collected in London are conveyed to different parts of the country, to be used as manure. The sloops and cutters from Hull take in their cargoes of bones above London Bridge. These are stowed in the hold in a more or less putrid state: here they ferment, and diffuse a putrid odour to a great distance; and when the cargo is discharged at Hull, they are frequently reeking and smoking from decomposition. This probably softens them, and allows them to be more easily crushed at the mill. Bones are also imported into Great Britain from South America and other parts, and some of the most celebrated battle-fields of our own time are also said to have furnished considerable supplies of this valuable commodity.

Professor Johnston remarks that, while 100lbs. of bone-dust add to the soil as much organic matter as 33lbs. of horn, or as 300 or 400lbs. of blood or flesh, they add at the same time two-thirds of their weight of inorganic matter, consisting of lime, magnesia, soda, common salt, and phosphoric acid (in the phosphates), all of which must be present in a fertile soil, since the plants require a certain supply of them all at every period of their growth. These substances, like the inorganic matter of plants, may remain in the soil, and may exert a beneficial action upon vegetation after all the organic or gelatinous matter has decayed or disappeared. In order to bring the bones into a state in which the substances contained in them can be more readily taken up by the roots of plants, and at the same time be more uniformly distributed through the soil, the bone-dust is mixed with one-half its weight, and sometimes with its own weight, of sulphuric acid, diluted with from one to three times its bulk of water. After two or three days, with occasional stirring, the bones are entirely dissolved or reduced. The solution or paste may be dried up with charcoal-powder, with dried or charred peat, with sawdust, or with fine vegetable soil, and applied with the hand or with the drill to the turnip-crop; or it may be diluted with fifty times its bulk of water, and let off into the drills with a water-cart. This stimulates the young plants, and causes them to pass quickly through the first stage into the rough leaf, and thus they in great measure avoid the attacks of the fly and other insects, by which the tender plants of tardy growth are often entirely cut off.

In some parts of the world bone is used as a fuel. In the treeless steppes of Tartary, and in the pampas of South America, it is considered that the bones of an ox will produce heat enough for the cooking of its flesh.

Many poor people in London gain a precarious livelihood by collecting fragments of bone in the streets, which they sell to the manufacturers of sal-ammoniac. The dealers in marine stores also purchase bones, which they dispose of in a similar manner, or to the soap-boilers. The bones thus collected are thrown into a cauldron of water, and boiled, for the purpose of clearing them of their fat, which is collected from the surface of the water, and used in the composition of soap.

The bones are then thrown into large retorts, and subjected to destructive distillation, the matter of the bone being resolved into its constituent elements from which new compounds are formed. Some of these pass off in vapour or gas, but the fixed principles remain in the retort. The volatile portions are carbonic acid and various combinations of hydrogen and carbon, forming different kinds of inflammable air, together with water, holding carbonate of ammonia in solution, and a peculiar oil, which is collected and afterwards employed to feed the lamps burning in small close chambers, the sides of which thus become covered with LAMP-BLACK. Towards the conclusion of the process, muriate of ammonia and sulphate of soda are formed: the latter is separated by dissolving in water and crystallizing, and the former (which is the sal-ammoniac, the great object of the manufacture) is obtained by sublimation.

The mass remaining in the retorts consists of the earthy and saline portions of the bone, blackened by the carbon of the animal matter, in which state it is called *ivory black*, *bone black*, and *animal charcoal*. This substance has a remarkable attraction for organic colouring matter, and is largely used for removing the colouring matter from syrup in the refining of sugar, and in the purification of many other organic liquors. By exposing ivory black to an open fire, the carbon is driven off, and the bones are nearly blanched. These are reduced to powder, which is used for making the cupels of the assayer [See ASSAYING], also as a polishing powder for plate and other articles, and also by the manufacturers of phosphorus for making lucifer matches.

In the above process the inflammable gas might be collected, purified, and used for gas-lighting, in which case the only product thrown away would be the carbonic acid.

BOOKBINDING. The demand for books at the present period of our history, so greatly exceeding that of any former time, has had the effect of bringing together trades which before were scattered, and of supplying by machinery that which was formerly accomplished by manual skill and dexterity. This is the usual effect of a greatly increased demand, the conversion of trades and individual occupations into manufactures, and although the production of a book handsomely bound in cloth, with a figured or embossed cover, and gilt ornaments, and lettering, would seem to depend for its production more upon individual skill than upon large and complicated machinery, yet here, as in so many other cases, the manufacturer has, to a great extent, superseded the mechanic.

Nearly all the trades subsidiary to the production of a book have passed through similar mutations. The paper on which it is printed is no longer made by the slow and costly process of moulding or framing a sheet at a time, but is produced with wonderful rapidity by means of highly complex and ingenious machinery: the ink with which it is printed is made in vast quantities in factories specially devoted to that sole object: the boards which form its sides are a distinct object of manufacture; the cloth which covers it brings into play textile machinery, the most elaborate in the world: the printing press which works off the copies is specially adapted to the steam engine, which sets it in motion with admirable speed and precision. Had it not been for changes such as these, which belong almost to our own day, the thirst for knowledge, which now happily pervades all classes, could never have been allayed; education could not have diffused her blessings, and the best security for national peace and order would have been wanting. In all these cases, the machinery which has superseded hand labour in some directions has led to a vastly increased amount of hand labour and intelligence in other directions. There is now a greater demand than ever for type-founders and for compositors, for literary men and for artists; for engravers on wood and engravers on metal. And if in the binding of a book, the workshop has expanded into the factory, and if many of the manipulations of the binder are now superseded by machines, there are more folders, more sewers, nay, there are even more finishers than formerly existed; for the great demand for machine-bound books, so to speak, has led to a corresponding increase in the better descriptions of binding, which depend almost entirely on the taste and skill of the workman. The same principle is at work throughout the useful arts. A successful machine may supersede certain descriptions of hand labour, and cause for a time much privation and suffering, but it is sure to increase the demand for labour in other branches; a well ascertained fact which ought to be constantly borne in mind by the intelligent workman. He ought to seek every opportunity of acquiring skill in more than one department of his trade, so that should his services in one direction be superseded by a machine, he may be able to apply his skill in another.

The effect of machinery upon the literary man has been, and is, in many respects highly beneficial. It is gradually raising his occupation into a profession, entailing the necessity of solid acquirements, an accurate style and business-like habits. He no longer writes under the uncertain favour of a patron, whose smiles must be purchased by the sacrifice of independence: he has now no occasion to dress like a man of fashion, or take charity in the shape of a humiliating "list of subscribers" to his work. The public is his patron, and his publisher his best friend.

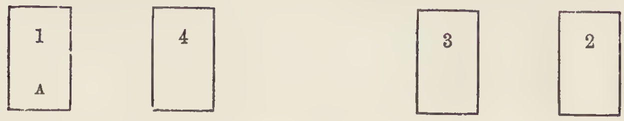
Machinery has also had a marked effect in raising compositors into a highly intelligent and respectable class. It has increased their numbers and improved their efforts. Men who are constantly engaged in perpetuating information and intelligence must to a great extent become informed and intelligent. The compositor, the reader or corrector of the press, must be constantly assimilating some, at least, of the intellectual food which they assist in preparing for the world. Their labour can never be superseded by machinery, although machinery may greatly increase its extent and importance, and just in proportion as they become skilful and intelligent do they become valuable to the literary man with whom they are so intimately connected.

When the author and the compositor have accomplished their respective duties, the one in supplying "copy," and the other in "setting it up" in type, the manufacturing processes of a book may be said to begin. For the sake of convenience and economy, books are printed in sheets, the sizes of which are named according to the number and size of the pages in each sheet. The largest size is termed *folio*, (Latin *folium*, a leaf or sheet of paper;) the next size is *quarto*; then follow *octavo* or 8vo; *duodecimo* or 12mo, 16mo, 18mo, 24mo, 32mo, &c., which contain on one *form* or side of the sheet 2, 4, 8, 12, 16, 18, 24 and 32 pages respectively; but as all the sheets are *perfected*, that is, printed on both sides, these numbers must be doubled to give the actual number of pages in each sheet. Each of these sizes also admits of many varieties: thus, an octavo, although always consisting of 16 pages, may be *square octavo, royal octavo, super-royal octavo*, &c., which leads to very great complication.

The arrangement of the pages of one side of a sheet or of a form in their proper order, and the wedging them up in an iron frame called a *chase*, preparatory to their being printed, is called *imposing* a sheet, and as the sheet is to be printed on both sides, there are two forms to be imposed for every sheet, an *inner* and an *outer form;* the outer form containing the first page of the sheet or of the book, and all the other pages which, when the sheet is folded, fall in their proper order with the inner form, which contains the second or left-hand page of the sheet, and all the other pages which, when the sheet has been folded and cut open, fall also in their proper order. The following diagrams will serve to illustrate some of the most important sizes of sheets,

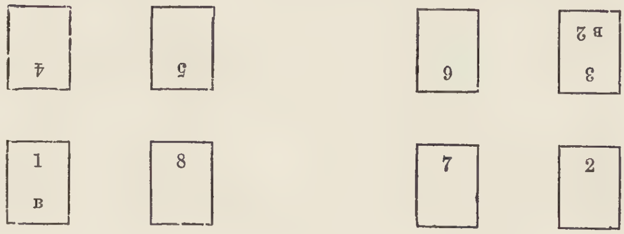
1. Sheet of Folio.

Outer Form. *Inner Form.*



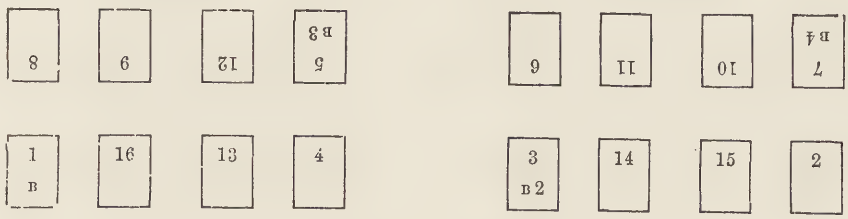
2. Sheet of Quarto.

Outer Form. *Inner Form.*



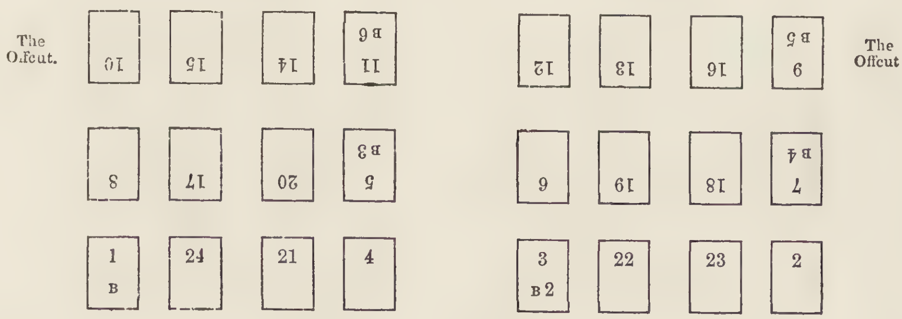
3. Sheet of Octavo.

Outer Form. *Inner Form.*



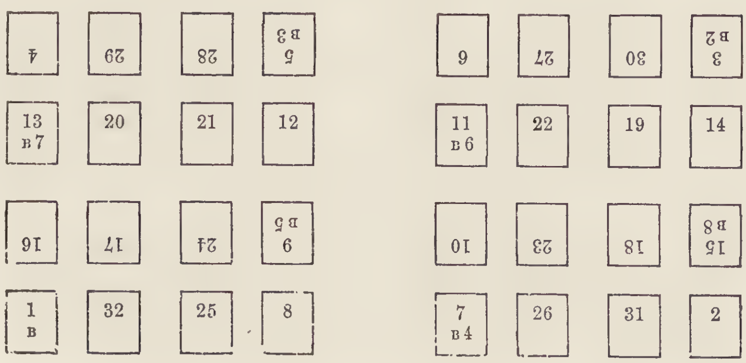
4. Sheet of Twelves.

Outer Form. *Inner Form.*



5. Sheet of Sixteens.

Outer Form. *Inner Form.*



and the order in which the pages must be arranged in imposing the two forms of each sheet. It will be seen that by examining the *folios* or numbers of the pages of every two adjoining pages in a quarter, their sum makes one more than the number of pages in the whole sheet: thus in a folio $1 + 4 = 5$ are imposed together; in a quarto $1 + 8 = 9$; in an octavo $1 + 16 = 17$; in a duodecimo $1 + 24$; in sixteens $1 + 32$, in eighteens $1 + 36$, and so on in every other size; this combination continues through all the other adjoining pages, according to the order in which they lie in the chase to be printed.

As a complete book or volume consists of a number of sheets, properly folded and following each other in the order of the folios or pages, it is necessary to have some distinguishing mark to each sheet for the convenience of the printer, the folder, and the binder. The numbers of the pages would be too slow and tedious for the purpose; their chief use being for the sake of convenient reference on the part of the reader. The printer, therefore, inserts at the bottom of the first page of every sheet, what he calls the *signature* of the sheet,[1] and this usually consists of the letters of the alphabet, the first sheet being usually marked B, (A being reserved for the title, contents, &c., which are usually printed last,) the second sheet is marked C, and so on throughout the letters of the old Roman alphabet, which did not contain the letters J V and W: these are therefore omitted. When this alphabet is exhausted, the twenty-third sheet is signed AA or 2A, the twenty-fourth BB or 2B, and so on to the end. The third alphabet is written AAA or 3A, and so on. It is also used for the purpose of guiding the printer in imposing and the folder in folding, to insert other minor signatures at the bottom of the third page of every sheet. Thus, if the signature of the first page of an octavo sheet be B, the signature at the bottom of the third page of the same sheet is B2, and in some cases the fifth and seventh pages are marked respectively, B3, B4. In some cases, especially in books printed in France and Germany, numbers instead of letters are used for the signatures. If the work be in two or more volumes, the number of the volume is added to each sheet, thus, VOL. II. B would be the signature of the first sheet of the second volume. In foreign books this signature would be simply II 1. In both cases the number of the volume is inserted at the left hand bottom corner, and the letter or numeral near the right hand bottom corner.

In imposing a sheet of twelves or duodecimo, eight pages in each form are arranged together in the manner of a small octavo sheet. Above these eight pages, with a wider space between, four pages are arranged in each form, forming what is called the *offcut*. In folding the sheet, these four pages are first cut off, and the remaining eight folded like a sheet of octavo. The offcut is then folded down the middle twice, and inserted within the fold of the sixteen pages, thus forming altogether the required number twenty-four. In a sheet of this kind the signatures are carried to B 6, B 5 being the first page of the offcut, and however numerous the pages may be in a sheet with one signature, if they are all inserted, they are continued to the last odd page before the middle of the sheet, but they are never carried beyond the middle. In strictness it is not necessary to insert more than the first two to indicate the first fold of the paper, and the first of the offcut. The others only disfigure the pages, and are not of much use to the folder, who has only to keep the signatures on the outside, and the pages must be folded correctly. In French books the first page of the offcut is often indicated by some small mark printed at the bottom, such as . .

No. 4 of the diagrams p. 153 is a sheet of twelves imposed with the first signature of the offcut in the inner form. By this arrangement it rises more conveniently for the folder, as it saves her the trouble of turning the offcut over every sheet. No. 5 is a sheet of sixteens to fold without cutting.

The sheets are delivered by the printer to the binder[2] in one of two arrangements. Suppose an edition of 1,000 copies of an 8vo work is to bound; the printer either delivers at once 1,000 copies of signature A, 1,000 of B, and so on to the end, or he causes them to be previously *gathered* into *quires;* that is, a single sheet of Z, supposing that to be the last sheet in the book, is taken, and upon this is placed a single sheet of Y; on this is placed a single sheet of X, and by proceeding in this way in a retrograde order, the gatherer at length arrives at B, the sheets being all in the proper order for folding. He then takes the title, contents &c., (signature A) and folding all the sheets together into a quire, lays them aside and proceeds to make up or gather a second quire, and so on till the whole 1,000 copies have been gathered.

The folding is performed at the binder's by females educated for the purpose. They are seated before a long flat board or bench, and each folder, placing the open quire of sheets before her, and with a folding-stick or paper-knife in her hand, folds the sheet in such a way that one page shall be exactly opposite to another in each sheet, taking care that the signatures shall fall properly. The folding is accomplished with remarkable precision and despatch, the result of long practice. A good folder will fold 500 octavo sheets per hour, but the usual average is about 300. In folding twelves with an offcut, the time occupied in folding is usually doubled.

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(1) This is sometimes improperly called the *catch-word.* The catch-word is the first word of every page after the first, inserted at the right-hand bottom corner of the preceding page, for the purpose as it was supposed of assisting a person in reading aloud, and insuring the correct turning over of the pages. It is seldom used in modern printing.

(2) In preparing this notice of bookbinding, the Editor wishes to express his obligations to Messrs. Remnant, Edmonds & Remnant, of Lovell's Court, Paternoster Row, for allowing their processes and machinery to be inspected and copied. In this large and well-ordered establishment, 30,000 volumes per week are frequently done up in cloth, or bound in leather.

When the whole of the impression has been folded, the copies are knocked evenly together, and put into a hydrostatic press, for the purpose of compressing them into a compact form. If the work be newly

Fig. 165. FOLDING.

printed, care must be taken not to allow it to *set off*, as the fresh ink has a tendency to make an impression on the opposite page, as was generally the case with new books when compressed by the old method, which was to beat them on a large smooth stone with a cast-iron bell-shaped hammer weighing 12 or 14 lbs. This required some skill so as to compress or condense the sheets without marking them with the edge of the hammer, and to give the paper a smooth polished surface. This process was very much improved some years ago by Mr. Burn of Hatton Garden, who contrived a rolling press, Fig. 166, consisting of two iron cylinders, mounted and set in the

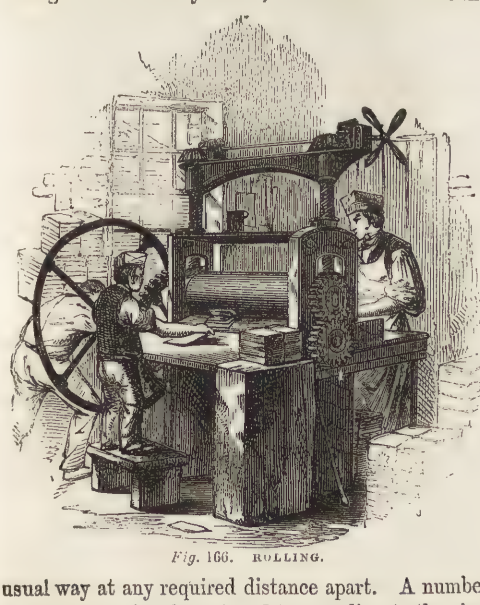


Fig. 166. ROLLING.

usual way at any required distance apart. A number of sheets, varying from 6 to 14, according to the size, being placed between two tinned iron plates, are passed through the rollers. This method not only renders the paper smoother than by hammer-beating, but the compression of the book is $\frac{1}{8}$th greater, a very desirable object, inasmuch as the book-shelves will contain nearly $\frac{1}{8}$th more books. These superior effects are also produced by the rollers in $\frac{1}{20}$th of the time required by the hammer. This method is now adopted for books that have been printed some time, in which the ink is properly set, and also for books that require re-binding.

After pressing, rolling, or hammering, each book is collated, to see that all the signatures run properly, and the plates (if any) are inserted in their proper places. The waste leaves are added at the beginning and end; the back and head are then knocked up square, and one side of the book is placed on a pressing board of the size of the book itself, and another similar board is laid on the upper side of the book, taking care to let the back of the sheets project about half an inch between the two boards. The workman then grasps the boards firmly between the thumb and fingers of the left hand, and lowers them into the cutting-press, Fig. 167, which consists of two strong wooden cheeks *c c* connected by two slide bars *b b*, and two wooden screws *s s*. The use of the two guides on one of the cheeks will be

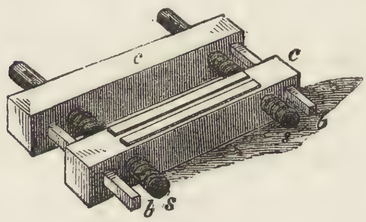


Fig. 167

explained hereafter, but it may be remarked that when these guides are not wanted, the press is turned completely over, so that these guides may be at the bottom, and out of the way. When the sheets are lowered between the cheeks *c c*, the press is screwed up tight by working an iron bar in the heads of the screws. The man then passes a tenon saw across the back of the sheets, so as to make a number of grooves, according to the size of the book, for the reception of the cords or bands for holding the threads in the sewing, and also for securing the boards which are to form the side covers. The number of bands depends upon the style of binding or method of finishing the book; periodicals, such as the Quarterly or Edinburgh Review, and boarded books, or books bound in cloth, have only two bands. But in the better descriptions of binding, 32mos sometimes have three bands; 18mo, 12mo, 8vo, and two-leaf 4tos, have 4 bands; royal octavo and whole sheet 4tos, 5 bands, and folios from 5 to 7 bands. In addition to these grooves for the bands, a groove is also formed at each end for the *catch* or *kettle* stitch. Supposing a book with two bands is to be sewed, it is taken to the sewing-press, Fig. 168,[1] which is a

(1) This press is arranged for three bands, but for the sake of simplicity the description refers to two bands.

stout flat board *b b* containing an upright screw *s* at each end supporting a top rail *r* which rises and falls

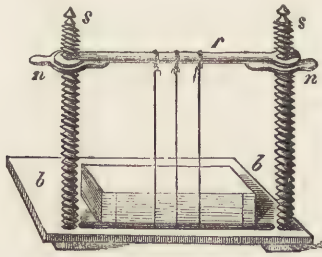


Fig. 168.

on the screws by means of nuts *n n*. Attached to this rail are several cords corresponding with the grooves sawed in the back, and these cords are secured by being fastened to brass keys, one of which is shown in Fig. 169, passed through the aperture in the bed of the press, while they are tightened by turning the nuts *n n*, so as to raise the top rail. The book to be sewed being placed on the board *b* with the title uppermost, the sewer first takes the fly-leaf or end paper if such there be, or sheet A of the book, and turning it over so that the title page may lie with its face on the board, she places the grooves in it so as to correspond with the stretched strings or bands. She then passes the left hand into the opening of the sheet, and with the right pushes the needle through the right hand kettle-stitch; the left hand receives the needle and returns it out through the first groove above the stretched string; the right hand draws the needle complete'y through, and passes it through the same groove below the stretched string; the left nand takes the needle and passes it through the second groove above the string, and the right hand returns it below the second string; and lastly, the left hand returns the needle through the bottom kettle-stitch. The thread is then drawn so as to lie evenly in the angle of the sheet, a small piece being left projecting through the back at the top kettle-stitch. The sewer then takes the second sheet, and turning it over upon the first, inserts the stretched strings into the sawed grooves at the back. She passes the needle through the bottom kettle-stitch, and proceeds as before, passing the needle in and out round the bands, only proceeding up the sheet instead of down. When the needle comes out through the top kettle-stitch, the thread is drawn tight and secured by tying it into a knot with the end projecting from the first sheet. These two sheets form a sort of foundation for the subsequent sheets, which require a less elaborate sewing. Two sheets are taken at a time, and the thread is drawn through the grooves of each alternately. Passing the needle through the top kettle-stitch of the lower sheet, then out above the first band; then into the upper sheet below the first band; then out above the second band; then below this band into the lower sheet; then out through the kettle-stitch of the lower sheet; and lastly, this lower sheet is secured to the previous sheet by passing the thread round its lower kettle-stitch. Two more sheets are then taken, and in this way the sewing is continued with great rapidity. When one length of thread is nearly exhausted, another is taken, and joined to the former by a knot. This kind of sewing is called *up and down work*, and presents the following arrangement in the sheets of the book,—

Fig. 169.

the sheets showing two threads and one thread alternately, as the reader will find by examining any boarded book, or a book bound in cloth. When the sewing of one book is completed, the thread is secured at the kettle-stitch, and cut off. A second book is sewed upon the first, upon the same bands, until the press is full. The bands are then loosened by slipping off the keys, and the books are separated from each other by severing the bands, care being taken, for some descriptions of binding, to be noticed hereafter, to leave a sufficient portion of the bands projecting on each side of each book for the purpose of securing the boards.

There are various kinds of sewing, depending on the size of the book and the style of the binding.

Fig. 170. SEWING.

The commonest kind of sewing, such as we have attempted to describe, is called *sewing two sheets*, or *up and down work*. In some kinds of fine binding the sheets are sewed *all along*, and only one at a time; that is, the thread is passed round every band, so that supposing there were three bands, the sewing in every sheet would present the following appearance:—

Where it is an object to compress the book into the smallest possible compass, fine silk is used instead of thread, as occupying less space. To prevent injury to the book by sawing grooves for the bands, which

cause the book to wear out much faster, (for the holes thus made gradually enlarge in size until the book falls to pieces,) a method of sewing is adopted without any grooves, tapes being used instead of strings. The only holes made in the sheets by this method are those of the needle, which is passed in and out above and below the tapes, and the sewer forms her own kettle-stitch with the needle. This kind of sewing is shown in Fig. 170. It requires more care than the former to keep the sheets even, and when well done the effect is excellent, for by this plan the book opens flat at any part, the fold of the sheet starting up fully to view when the book is opened.

When the books are folded and sewed, they pass from the female to the male department of the establishment. The first thing that is done is to secure the sewing by brushing a layer of glue over the back of each book, and covering the glue with a shred of paper or coarse thin canvass cut to the size of the back. If the book is to be boarded or bound in cloth, canvass is used of the same length as the back, but about half or three-quarters of an inch wider on each side, the projecting pieces serving to secure the side boards, as will be noticed presently. When the glue is dry, the book is laid flat between a couple of boards, and the projecting side and bottom edges are cut off tolerably true with a large knife kept sharp by frequent whetting on a dry stone. The folds of the sheets are not cut through; the only object of this trimming being to give the book a neat appearance. Then comes the operation of rounding the back, which is done by placing the book on its flat surface, and drawing the back on one side, gently tapping it with a broad-faced hammer: the book is then turned over upon its other surface, and the operation repeated, by which means the back is brought into a convex form. Each book is then placed separately between a couple of boards, with the back projecting, and is thus lowered into a screw-press, which is screwed up tight. The workman then, by a succession of blows, applied somewhat obliquely up and down one side of the back, depresses that side, and causes a ridge to project over the board. He then repeats the operation on the other side, by which means the back is depressed at the two sides, and is raised in the middle; a few gentle taps in the middle and some finishing blows at the sides complete the rounding, and its effect is to form the side edges into a concave groove, the concavity of which corresponds with the convexity of the back, and the grooves formed at the two boundary lines of the back allow the boards or side covers of the book to fall in so as to present an even surface at the sides.

The books are now to be placed in thin cases, and the outside fly-leaf being pasted to the boards, the books are built up between wooden boards, the backs of the books outwards, and projecting; and this pile is placed in what is called a *standing press*, (Fig. 171,) consisting of a well-oiled iron screw working in a nut, and the upper bed of the press is screwed down with great force by means of an iron bar inserted into the inverted head of the screw. To economise labour, the pile, which constantly varies in size, is made to rest upon a number of boards, which diminishes the distance between the upper and lower beds of the press. There the books are left for some hours to undergo the requisite compression.

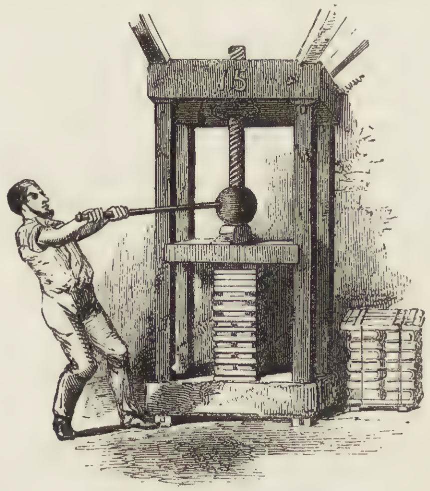


Fig. 171. STANDING PRESS.

The mill-boards which form the solid substance of the cases are supplied to the binder in sheets, varying in size from $17\frac{1}{4}$ inches by $14\frac{1}{4}$, for the smaller sizes, up to 41 by 31 inches. The binder cuts up these sheets to the required size with great precision and rapidity, by a machine (Fig. 172) constructed for the purpose. It consists of an iron frame, one-half of which

Fig. 172. BOARD-CUTTING MACHINE.

is covered with a horizontal plate, or table, for holding the board. At the inner edge of this table is a holdfast, or bar of metal, extending across the frame, moving on a hinge at the opposite side, and connected by a hinged lever on the near side with a treadle. The lower surface of this bar is furnished with file teeth, for holding the board fast. Just beyond this holdfast is a straight, fixed bar, with a square cutting edge, and by the side of this is a curved bar, or knife, mounted on an axis, and balanced by a weight at the further side and furnished with a handle at the near

side. The edge of this curved bar forms, with the fixed bar, a pair of shears, for cutting the boards. The gauge being set at the proper distance, the board is placed flat on the table, and its rough edge is first cut off. This is done by sliding the board along until the edge just projects beyond the shears. The man then puts his foot on the treadle, which brings the holdfast down, and secures the board; he next forces the curved blade down against the fixed blade, which cuts the board to a clean, smooth edge. Then, releasing the board, by lifting his foot off the treadle, and raising the knife, he passes the board up to the gauge, which is furnished with an edge or chamfer, and stops its further progress: the board is cut through as before, the piece falling into the bin beneath. In this way the board is cut up into three or four long strips, the other long edge, nearer the left hand, being cut off while it rests on the table. A number of boards being thus cut up, each strip being sufficient for two, three, four, or more boards, the strips are again passed through the shears, and cut to the proper size of the books they are intended to cover. Such is the precision of this machine, that when all the pieces thus cut are piled up and knocked together, they appear to form a solid parallelopipedon, with perfectly sharp edges, in consequence of all the pieces being of the same size.

The cover of the book may be of leather or of cloth; but in either case it is ornamented at the back and sides with a pattern enclosed within a figured or flowered border, with different toolings and devices for the back, and blank borders for the gilt lettering or other ornaments. These are stamped, by means of certain presses, varying in power, with the material to be embossed. The largest press which is used for embossing leather, is a ponderous fly-press, Fig. 174, situated in the cellar of the establishment. It consists of a solid iron frame, resting on a brick foundation, and well secured by iron ties. The lower bed of the press (also of iron) is perforated with two openings, into which a gas-pipe, formed like a fork with two prongs, and connected with a flexible tube, is inserted, for the purpose of heating the lower bed, upon which the metal die containing the pattern is placed, and by this means the die is kept at a tolerably steady high temperature, which is found most favourable for embossing. The dies are formed either of steel or brass, the latter being the more common. The dies are cut or chased by hand; but, for some patterns, consisting of regular curves, they can be more economically turned in the lathe, in which case brass must be used. The counter die, which is attached to the upper bed of the press, is formed by the man who manages the press, by glueing a number of pieces of millboard together, and glueing them to the surface of the upper bed. By swinging the arms of the press round, the lower surface of the millboard is brought down with amazing force upon the metal die, and the softer material takes the impression of the harder. The man then cuts and trims and adjusts the counter die, every now and then taking impressions on paper; and when he is satisfied with his arrangement, he proceeds to emboss the leather pieces cut to the proper size for covering the book. In order that he may place the leather evenly in the press, so as to receive the impression in the exact spot required, the lower die is furnished with a millboard collar (Fig. 173), so that all he has to do is to place the leather, face downwards, on the square, or whatever figure it may be, which is the exact size of the leather, making the two upper corners of the leather coincide with the corners *a b* of the collar. This being done, the embosser, who is seated in a pit before the frame, directs the man on the floor above to work the press. This man swings round the ponderous arm, furnished with two huge balls at its extremities, and by the weight as well as the centrifugal force of this arm, the upper bed is jerked down upon the lower one, and the leather, in an instant, takes the impression of the die. Every piece of leather requires to be passed three times through the press,—once for the back, which is, of course, of a different pattern to the sides, and once for each of the sides. If the two sides are of the same pattern, the man embosses all the leathers on one side,—say the left,—and, in order to save the necessity of turning round and re-adjusting the die, he carries the leathers to the other side of the press, and then works all the right hand sides.

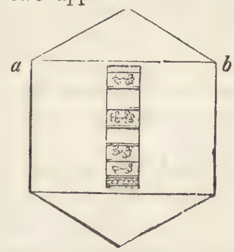


Fig. 173.

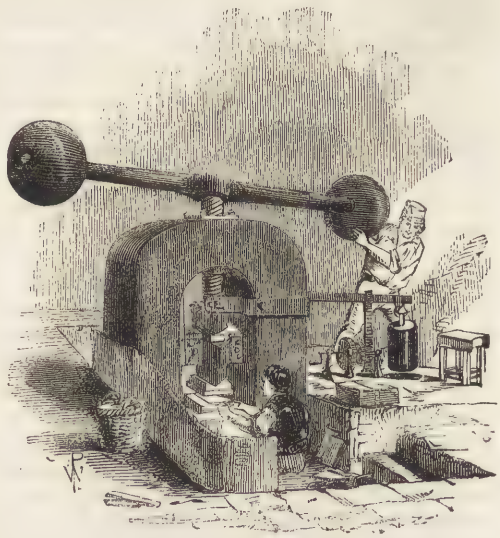


Fig. 174. EMBOSSING PRESS.

Cloth covers are embossed after the boards are inserted. The cloth which is now consumed in such enormous quantities in bookbinding, is manufactured for the purpose in Manchester, and is sent up to the London dealers in the article, who dye it of various colours, and glaze or calender it, and send it to the binders in rolls or pieces, each forty yards long and thirty-six inches wide. The cloth is cut up to the

proper size of the cover, an extra quantity being allowed for the overlap within the boards. The cases are then made up, with great rapidity, by two men, one of whom covers the inside with a layer of glue; then places two mill-boards in their proper position on the cover, so as to form the stiff sides, the space between the two depending, of course, on the thickness of the book. He then turns the cover over, and rubs the cloth firmly down with a cloth rubber shaped something like the stone muller used in colour-grinding. He then tosses the cover to a man, who places a strip of paper or canvass along the inside of the back between the two boards, and then folds down the projecting edges of the cloth over the boards, smoothing them down with the edge of a flat piece of stick with a blunt point at each end, and then drawing the point of the stick down the boundary lines between the back and the sides. The two men complete about 100 covers in an hour.

When the covers thus formed are perfectly dry, they are embossed and gilt. The ornaments which are simply produced by pressure are called *blind-blocking*, and when done by hand *blind-tooling;*

Fig. 175. GOLD-BLOCKING PRESS.

while the gilt ornaments or lettering are called *gold-blocking* or *gold-tooling*. The machines employed in both descriptions of ornament are called *blocking-presses*, and they do not greatly differ except in power from the fly-press already described. The ornamental pattern for the back or sides is cut out in a thick plate or block of brass, and is fixed in the upper bed of the press by means of a dove-tail joint. This upper bed is furnished with a cavity containing a gas-pipe with a row of jets for heating the die by conduction of heat from the upper bed. The cloth covers are inserted within metal rules, which serve as a gauge, by a man who sits before the press, while another man swings round with all his strength a long lever, whereby the upper bed is brought down a few inches upon the case in the lower bed, and embosses the impression. When the cases are completed in this way, they are taken to the gilders, who cover the parts intended to be gilt with a thin layer of ovalbumen or white of egg, called *glaire*, and then with a film of leaf-gold. [See GILDING.] The covers are then passed to a gold-blocking press, (Fig. 175,) containing a plate or block, in which are set up the lettering and other ornaments intended to be gilt. The letters may either be set up in movable type, or cut out of one solid piece of brass. For the ornaments, the latter course is adopted. The block is heated by jets of gas playing in a cavity of the upper bed, and the cover being carefully introduced into a gauged bed, the man moves a handle round, which brings the heated plate with a gentle and equable pressure down upon the cover, and permanently fixes the letters or device. As the covers are removed, they are taken by a boy, who wipes off the superfluous gold with a piece of thick rag, which thus gradually absorbs the fragile leaf, and in the course of two or three months this rag is so valuable that it is sold for perhaps 20*s*. or 30*s*. to the gold refiner, who burns it in a covered crucible, and thus recovers the precious metal.

The covers thus formed are next adjusted to the books, which we left in the standing-press. The covers are secured to the books by glueing the canvass strips which project on each side of the back to the boards, and to conceal this arrangement as well as the uncovered parts of the boards, and also to give a neat finish to the book, some coloured paper called *lining paper* is glued in. The books are lastly put into the standing-press for a few hours, and may then be said to be finished.

We have thus traced the various processes concerned in binding a cloth-boarded book. They consist of gathering, folding, and sewing the sheets; glueing and rounding the backs; cutting the edges; making, embossing, and gilding the covers; and lastly, securing the covers to the books. In a large establishment, such as Messrs. Remnant's, the whole impression of an octavo work, consisting of 1,000 copies, can be done up in cloth in the course of about six hours; in which case, however, the cloth covers are prepared a day or two before, all the information required for the purpose being the thickness of the book, which is known by stating the number of sheets contained in it. The title and the style of ornament, colour of the cloth, &c., are also determined. A thousand covers or cases can be prepared in one or two days. The book itself can be folded, stitched, glued, and rounded, the edges trimmed, and the book mounted in cases and pressed, all within six hours. This is indeed an extraordinary example of the power of numbers of skilful workpeople, and the effect of a refined system of division of labour.

The method of binding thus far described applies chiefly to those books which are issued in large numbers, and whether the covers be leather or cloth, there is no very great difference in the methods adopted. In leather bindings, such as in Bibles and Prayer Books, the edges, instead of being trimmed with a knife, as before described, are cut through with a *plough*, so that there is no necessity for cutting

open the book before reading it. The bookbinder's plough consists of two upright cheeks of wood, *c c*, (Fig. 176,) connected together by a wooden screw *s*, and a couple of guides, *b b*, fixed into one cheek, and moving in square holes in the other. The screw passes through both cheeks, so that by turning it

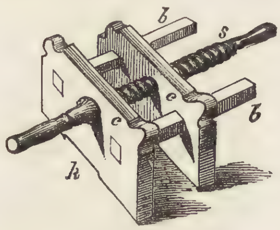


Fig. 176.

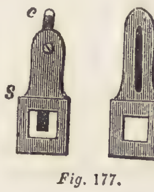


Fig. 177.

round in one direction the cheeks are brought nearer together, and in the contrary direction moved farther apart. Into one of the cheeks at *k* is fixed a cutting-knife, (Fig. 177,) a double-edged, pointed blade, of which two forms are given. The book to be ploughed is placed between a couple of boards in the press, with the edges projecting as much as is required, and one of the cheeks being placed in a groove of the press, the point of the knife is brought up to the book, and moved backwards and forwards against it, the workman at the same time giving the handle of the screw a twist, which advances the knife forward until the cutting is completed. (Fig. 178.) The white edges of the book in common binding are then *sprinkled*, whereby that speckled or mottled effect is given to them, which prevents them from soiling, and also improves the appearance of the book. This is done by mixing up some coloured chalk, umber, Venetian red, or ochre, in a little size and water, and dipping a brush into the mixture, so as just to wet the hairs; the man holds a long piece of wood a few feet over the books, and dashes the hairs of the brush against it, which causes a shower of minute drops of colour to rain down upon the edges of the books, a number of which are set up together for the purpose. When the desired effect is produced on the top edges, the books are turned over, and the bottom edges are treated in a similar manner, the man turning up one of the finished edges every now and then, to see that he is producing the same tint of colour at the bottom as at the top. The side edges are done in the same way, and the colour is fixed by placing the books in the bench press, and passing an agate burnisher over the edges, which produces a high polish, and prevents the colour from being removed by ordinary use. By these simple and expeditious processes a cheap and useful ornament is added to the books.

In the better class of binding, as in whole bound calf, gilt lettered, with raised backs, the boards are added after the glueing and rounding of the backs, for which purpose the sewer leaves small projecting pieces of string bands. The boards being cut to the proper size, a couple of holes are made in each board with a brad-awl, opposite each band, and the string being passed through these holes is secured with glue. In a book of three bands, the boards are held by six strings, three on each side, and each board is of course pierced with six holes. The books are then put into the standing-press for a few hours, after which the edges are ploughed, (Fig. 178,) the boards being slightly depressed below the edge to be cut off, the strings allowing them a little play before the cover is put on. In cutting the side edges, the workman takes care to preserve the concavity produced by the rounding, for which purpose he flattens the back by passing a flat tool between the edges of the boards, which are allowed to hang down loose, and the back. He then places the book between a couple of boards, grasps it tightly, and withdraws the flat tool; then lowers it into the press, and screws it up tightly. By thus flattening the back, the edges become flat also, and when they have been ploughed, and the book

Fig. 178. PLOUGHING THE EDGES.

is taken out of the press, the back starts into shape again, and the side edges become concave. After this, the edges are gilt or marbled. In gilding, the book is secured between a couple of boards in the press, and the edges being covered with glaire, a layer of gold leaf is laid on, and the agate burnisher being well rubbed over every part across the edges, secures the gold leaf, at the same time giving it a beautiful polish. When all the edges are thus gilt, paper is wrapped round them, to prevent them from getting soiled. When the edges are to be marbled, the books are sent out to the marbler's, who produces the effect of marbled paper by the following contrivance. A trough about two inches deep is filled with clean gum-water. Various coloured pigments, ground in spirits of wine, and mixed with a small quantity of ox-gall, are thrown upon the surface of the gum-water, and disposed in various forms with a quill and comb, according to the desired pattern. This being obtained, the book is tied between two boards, and the edges being dipped into the trough, the floating colours become attached; cold water is then dashed over the edges, which sets the colours, and brings them out clear.

The book is now ready to receive the *head-band*, which serves as a finish to the top and bottom of the

sheets, and assists in keeping the upper and lower parts of the hollow back in shape, when the book is closed. The book, still in the rough boards, is fixed by one corner in a small portable screw-press, as in Fig. 179, and a small strip of mill-board, placed on edge at the back, is secured by passing a needle and thread two or three times between the leaves through the solid back, and over and under the small strip; the thread, which is generally of silk or cotton, two or three colours being sometimes used, is then twisted or plaited over the strip, and when about a third or one-half is covered, it is further secured by a few

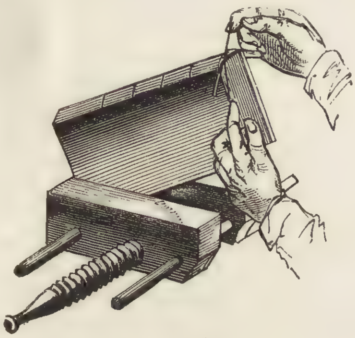


Fig. 179.

stitches through the solid back. The plaiting or covering is then completed, and is secured as before by sewing through the back. The superfluous portions of the strip are then cut off. This description of head-band is called *worked;* a commoner description, called *stuck-on,* is a piece of striped or coloured linen, enclosing a piece of cord, stuck or glued to the back of the book. The bands or raised projections at the back of the book are formed by glueing strips of mill-board, leather, or cord across them.

The book is now ready for covering. The leather may be calf, or morocco, or russia; but, whatever the leather, it is carefully chosen, so as to be free from blemishes, and of the proper size, and, being placed on a flat board, with the rough side up, the edges are pared thin with a sharp knife, so that in turning them over the board, they may not bulge out into unsightly projections. The leather is then damped, and covered with paste, and applied to the book, a few simple tools being used to smooth it down and press it into shape, to square the edges, and to raise the bands. The leather is neatly turned in at the top and bottom, and then folded over the head-bands. When the sides and edges are nicely smoothed and squared, the bands at the back are raised, and the spaces between them depressed, by working them with a bone paper-knife, and during all these manipulations the man every now and then moistens the leather with a bit of wet sponge. When the leather cover is properly arranged, the marbled or other lining papers are inserted, and the book is put into the standing press for a few hours, after which it is ready for tooling. But in some descriptions of binding, a good effect is produced by having distinct lettering pieces, of a different colour from the general binding. These are cut out separately, thinned at the edges, and attached by means of glue. The blind-tool ornaments of the book are put on by means of pieces of brass, cut into the desired pattern and shape, and mounted in handles, as in Figs. 180, 181.

Fig. 180.

Fig. 181.

If a long line, plain or figured, is to run up the sides of the book, it is cut upon the periphery of a disc of brass, Fig. 182, moving upon a central axis, and furnished with a long handle, which the man rests against his right shoulder, holding the tool near the axis:

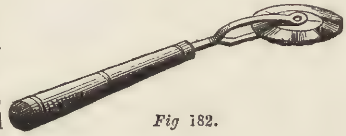


Fig 182.

in this way he can roll the tool the whole length of each side of the cover. All these tools are heated at a gas-stove, Fig. 183, a great improvement on the unwholesome charcoal brazier formerly in use. The small tools are pressed down with an equable force in those parts of the cover where they are wanted. Gilt tooling is produced by covering the parts to be gilt first with glaire and then with gold leaf, and then pressing the hot tool upon the part thus covered. On wiping off the gold with a rag, that part of the gold only is attached which came in contact with the hot tool.

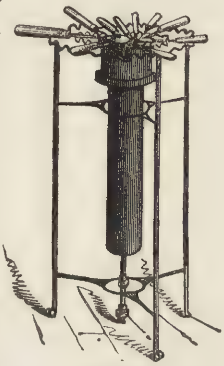


Fig. 183.

Lettering is performed commonly by a set of lettering tools, each letter of the alphabet being cut out in brass, and mounted in a wooden handle. Letters, numerals, &c., are kept of different sizes; but for words in common use, such as "Holy Bible," "Atlas," &c., tools are kept, with the whole word or words cut in them, as in Fig. 184. When the ornaments, lettering, &c., are complete, the book is finished off with polishing-irons, of various shapes and sizes, one of which is shown in Fig. 185. These are heated, and

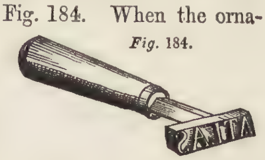


Fig. 184.

Fig. 185.

passed over the leather, and also over the marble lining-paper, &c.

We have thus gone over the principal processes concerned in binding a book. A few years ago, a method of binding by means of caoutchouc cement was patented by Mr. Hancock, by which the operations of sawing-in, sewing, rounding, and the use of

glue are dispensed with, and instead of leaves attached by thread stitches at two or three points, they are agglutinated securely along their whole length. This plan is admirably adapted for binding engravings, maps, manuscripts, and collections of letters, which have little or no margin left at the back for the stitching. The plan has been thus described:—"After folding the sheets in double leaves, the workman places them vertically, with the edges forming the back of the book downwards, in a concave mould, of such rounded or semi-cylindrical shape as the back of the book is intended to have. The mould for this purpose consists of two parallel upright boards, set apart upon a cradle frame, each having a portion or portions cut out vertically, somewhat deeper than the breadth of the book, but of a width nearly equal to its thickness before it is pressed. One of these upright boards may be slidden nearer to or further from its fellow, by means of a guide-bar, attached to the sole of the cradle. Thus the distance between the concave bed of the two vertical slots in which the book rests may be varied according to the length of the leaves. In all cases about one-fourth of the length of the book at each end projects beyond the board, so that one-half rests between the two boards. Two or three packthreads are now bound round the leaves thus arranged, from top to bottom of the page, in different lines, in order to preserve the form given to the back of the mould in which it lay. The book is next subjected to the action of the press. The back, which is left projecting very slightly in front, is then smeared carefully by the fingers with a solution of caoutchouc, whereby each paper-edge receives a small portion of the cement. In a few hours it is sufficiently dry to take another coat of a somewhat stronger caoutchouc solution. In forty-eight hours four applications of the caoutchouc may be made and dried. The back and the adjoining part of the sides are next covered with the usual band or fillet of cloth, glued on with caoutchouc; after which the book is ready to have the boards attached, and to be covered with leather or parchment, as may be desired."

Vellum binding is a distinct branch of the trade, and is applied to the binding of every description of account-book. The paper is first folded and counted into sections, which in foolscap generally consist of six sheets, and above that size, of four sheets. These are sewed upon strips of vellum, three strips being usually applied to foolscap folio, and a greater number for larger sizes. In sewing account-books, waxed thread is used as being stronger. After sewing, the first ruled leaf at each end is pasted to the waste paper and the marble lining paper inserted. The back is then glued, and when dry, the fore edge is cut and the back rounded, a rounder back and consequently a deeper hollow being given than in printed books. The two ends are then cut and the edges marbled. The head-bands are worked on a slip of mill-board as before described. Strong pieces of canvass or buckram are then glued at the top and bottom of the back and between each of the vellum slips. A hollow back is produced by soaking in water a strip of mill-board about a quarter of an inch wider than the back of the book and gluing it on both sides; it is then placed on a sheet of paper, and a roller corresponding to the curvature of the back of the book is placed upon it, and the strip is worked backwards and forwards on the roller, which gives it the semicircular shape. It is then dried hard before the fire. Another method is to paste a number of pieces of paper in succession upon a roller, and when thoroughly dry it is cut down lengthwise, thus forming two semicircular backs. Thin sheet-iron is sometimes used for the purpose. The milled boards are then cut out for the side covers. In large books it is usual to glue together two thin boards for each cover, and to insert between them the projecting ends of the vellum bands on which the book is sewn. The first and last fly-leaves are pasted to the boards, and after they are squared, the curved back above described is placed on, and a piece of canvass sufficient to extend over half the width of the book on one side to the same distance on the other side, is glued on the boards and over the back: this holds the hollow back firmly in place. The book is then ready for covering, for which purpose the leather is carefully pared all round and neatly put on. The covers are usually forril and vellum, white and coloured; smooth and rough calf and sheep; basil, smooth and grained, and russia. Forril and vellum covers are lined with paper and pressed smooth. When dry, they are fitted on the back and creased in the joints: the boards are then pasted and the covers pressed on them: when dry, the edges of the cover are pasted and turned in and the book again pressed: the cover is then washed with a sponge and paste-water, and then ruled off. If the cover be rough calf or sheep, it is dressed with pumice-stone and a clothes-brush. Smooth calf, basil, &c., are glaired and polished as in bookbinding. Rough calf books are usually ornamented by passing a very hot roller round the edges and sides of the cover. Large books are sometimes furnished with bands of russia leather worked on with thongs of vellum, which add to the strength of the binding and have a neat appearance.

BORACIC ACID. BORAX. [See Boron.]

BORING may be regarded as a branch of Turning; but in the former the tool is generally made to revolve while the work remains stationary, while in the latter the work revolves while the tool is stationary or nearly so. There are, however, exceptions to this, as in boring or forming the cylindrical cavity of ordnance both methods are adopted; in one, the gun revolves and the borer advances in a fixed axis, and by another method the gun is fixed and the cutter revolves. The former is adopted for brass guns, and as the gun revolves, its exterior surface is turned. Cannon are now always cast sold, and the cylindrical cavity is formed by boring into this solid mass. The gun is placed horizontally in the boring-mill, and is fixed to the axis of the mill by means of the square piece at the cascabel. In a boring-mill constructed by Smeaton, the gun is placed on

the horizontal axis of a water-wheel, and consequently revolves with the same velocity. On this same axis, Fig 186 is a toothed wheel which works two wheels,

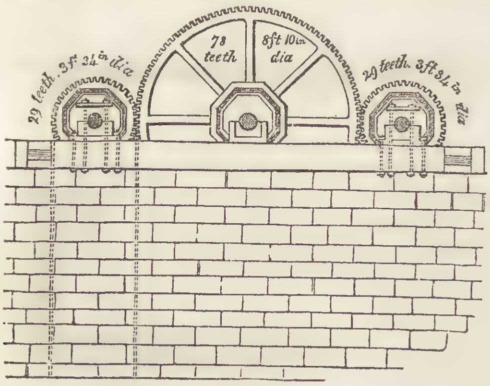


Fig. 186.

one placed on each side, and on the axis of each of these is a gun of smaller size. A bar of steel in shape and size like the coulter of a plough, is first applied at right angles to the axis of the gun. The narrow side of the bar is sharpened to a cutting edge, so as to have the form of one tooth of a very large saw, and this being opposed to the direction of the revolving motion of the gun, takes off an angular portion at right angles to the axis, until the cylindrical part connecting the head with the gun is so much diminished that the head falls off with the blow of a hammer. The boring is then commenced by exposing the revolving gun to the action of a steel cutter fixed to the end of a bar placed on a carriage and impelled continually towards the gun. The carriage, which slides in triangular iron grooves, consists merely of a bar on which the rack is pressed forward by the pinion P, Fig. 187, whose gudgeons are on a fixed frame BB, and this pinion works into a rack R. The axis of the pinion has mortised holes in it, through which, one end of the lever L is passed, and the other end is loaded with a weight W, which causes the pinion to propel the carriage and thus urge the boring bar towards the gun. In some machines, two pinions are attached to the same

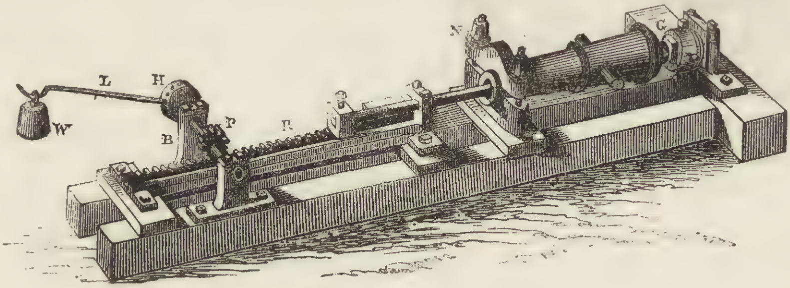


Fig. 187. CANNON-BORING MACHINE.

axis and act on two racks. In other cases the carriage is propelled by two upright levers, the end of one of which has a weight hanging from a rope passing over a pulley: the lower end of the upper lever acts on the upper end of the lower, while the lower extremity of the lower lever presses forward the carriage. This method is free from any inequalities arising from the teeth of the rack. According to another contrivance, a screw acting on the end of the carriage is used to propel it. The boring bar used in all these machines is a very strong wrought-iron bar of less diameter than the calibre, in order to allow the iron dust and shavings to be readily got out; its diameter is increased for some inches near the end B, Fig. 188, where there is a groove

Fig. 188.

for admitting the steel cutter T, the two upper angles of which are cut off obliquely so as to form an obtuse angled drill, the edges of which coming in contact with the revolving metal produce a conical cavity by taking off shavings from the solid metal. The first bore is smaller than the intended size. When this is completed, a second borer, consisting of a cross bit or rectangular piece of steel, with a cutting edge at each end, is put through a hole in the boring bar, and the edges of this cutter in revolving describe a cylindrical surface. When the bore is of the proper size and sufficiently true, a bit without a point and rounded off to the desired curve is used to form the bottom of the chamber. The cutters become magnetic in consequent of being continually rubbed in the same direction, and the boring dust is seen hanging from their edges when they are withdrawn. While the boring is being conducted in this way, the exterior of the gun is turned by appropriate turning tools. A wooden gauge or cut-out profile of the gun with its intended mouldings is applied from time to time to ascertain when the turning has been continued to the proper depth. The cyphers and arms cast on the gun are finished by a chisel. The touch-hole is drilled by stock and bit, or by drill and bow. The gun is then examined to ascertain whether the bore is free from holes: this is done with an instrument consisting of several elastic steel prongs with sharp points arranged in a circle: by moving this backwards and forwards in various ways, the points press against the side, and thus detect any hole that may exist. A lighted wax taper is also introduced, or the light of the sun is reflected by a mirror into the bore, by which means defects can be detected and examined by eye. The gun is proved by firing it with a large charge of powder, and also by forcing water into the bore

through a powerful force-pump, the touch-hole being stopped. All these precautions in boring and ascertaining the accuracy of the bore have greatly contributed to the present precision in artillery practice.

The boring of muskets and small arms will be more conveniently described in connexion with the processes concerned in the manufacture of GUN BARRELS.

The boring of cylinders for steam engines, blowing machines, working-barrels of large pumps, and other hollow cylinders of cast-iron in which pistons work, requires very powerful and accurate machinery. The cylinder is cast hollow, and the object of the boring machine is to convert the interior into a true cylinder. The machine shown in Fig. 189, was contrived at the time when accurately bored cylinders were required, in consequence of Watt's improvement in steam engines. In this arrangement the cylinder

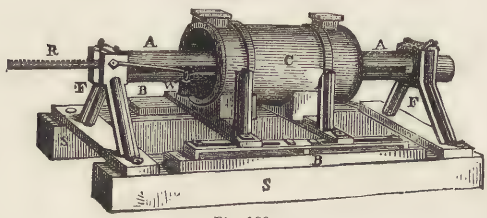


Fig. 189.

is placed horizontally, while the cutters revolve and advance by the action of some powerful prime mover, and the operation is commonly repeated three times, in the last of which the greatest care is required, and the engine is worked from the beginning to the end of the operation. This is also done, by some makers, in the finishing process of boring ordnance, the machine being kept at work through meal-times, day and night; for if it were discontinued while the cutter was only midway or in any part of its journey, and the cylinder allowed to lose the heat it acquires by the friction of the cutter, &c., a ridge and unevenness would be formed in the surface, which would greatly interfere with its proper action.

In the boring engine, Fig. 189, S S are two solid sills of oak, arranged parallel to each other and to sleepers let into the ground; at each end is a vertical iron frame, F F, for supporting gudgeons at the end of a long cylindrical axis or tube of cast-iron A A, which revolves by the prime mover. The cylinder C to be bored, is fixed over this bar on an adjusting framing B, and is supported by blocks below, and held fast by iron bands drawn down by screws in the top of standards. The cylinder is adjusted so as to be concentric with the axis A, and is held firmly by wedges driven under the blocks and standards. On this axis slides a cutter-head or piece of cast-iron, R T, Fig. 190, into which are fixed cutters *c c*. The tube A, shown

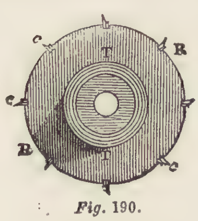


Fig. 190.

separately in Fig. 191, is divided by a longitudinal aperture *a* on each side, except at the ends, where it forms a complete tube to keep the two halves together. The cutter-head R T, Fig. 190, consists of a tube T,

Fig. 191.

Fig. 191, accurately fitted on the axis A, and a cast-iron ring R fixed upon T by four wedges. On this circle are eight notches for the reception of the cutters. The slide R is kept from slipping round with the axis by two short iron bars *b b*, which are put through the axis and received into notches cut

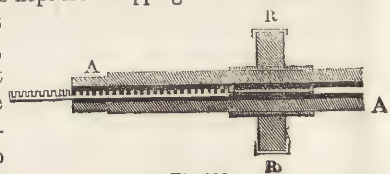


Fig. 192.

in the ends of the sliders R, and a bolt passing through the holes in the middle of the sliders at the end of the toothed rack R; a key put through the end of the bolt prevents the rack from being drawn back, and holds the cross-bars *b b* in place. The rack is worked by the teeth of the pinion P, and is kept in place by the roller O. The axis of the pinion and roller is attached to the standard F, Fig. 189, and the pinion is turned round by the action of the weight W at the end of a lever on the square end of the axis. By another contrivance, four small wheels are fixed at the right hand of A, Fig. 192. Another pinion fixed to the extremity of the axis, similar to the rack R, has at its other extremity a small screw, which works an interior screw fixed to the cutters R at *b*. Below the second pinion is another fixed on a horizontal axis parallel to A. At the other end of the axis is a fourth pinion driven by the first at the end of the hollow axis A. As the axis A revolves, the first pinion at its extremity drives the fourth, which by means of the third, fixed on the same axis with it, gives motion to the second; the second pinion, being fixed on an axis within F, unscrews the screw at the other extremity and makes the cutters advance along the cylinder. Sixty turns of the axis cut one inch of the cylinder.

According to Billingsley's method, the cylinder is placed with its axis in a vertical instead of a horizontal position, in order that the boring dust and shavings may fall out instead of wearing and impeding the cutters. By this arrangement the cylinder is bored throughout without changing the cutters, and a more regular bore is thus obtained. Another advantage is, that the cylinder does not deviate from its cylindrical form by its own weight, which sometimes happens when large and slender cylinders are laid on their side. There is also often a loss of shape by improperly strapping and wedging down.

Before the general introduction of cast-iron water-pipes, there was a great demand for wooden pipes, which were formed by boring the trunks of trees. For this purpose the tree was well secured to a carriage, and a vertical spindle, driven by a trundle

and face wheel, gave motion to a horizontal bar, carrying a borer or auger at its extremity. As this revolved, motion was given to another wheel, about whose shaft was a rope also attached to the carriage, so that as the borer cut, the tree was gradually drawn up to the work until the hole was cut through. A larger auger was then used, and the operation repeated until the bore was of the proper size. In some cases the tree was made to revolve against a fixed auger. In other cases the tree was fixed vertically, so that the chips could fall out as the work proceeded. An ingenious machine was also contrived for cutting out the core whole, so that it could be applied to other uses. In this case a hollow cylinder was formed, with a crown saw at the extremity, which, being made to revolve, cut its way into the tree, while the core entered the cylinder, and was thus preserved whole. A plan of this kind was patented by Mr. Murdock in 1810 for boring stone-pipes, the core forming round pillars of stone. An attempt was made to use the pipes as the common water-pipes of London; they were joined together by means of Parker's cement, but the vibration communicated to the roads by the carriages, loosened the joints and made the pipes leak.

A variety of boring tools, used in the arts, will be found noticed under AUGER.

One of the most important applications of boring, is in the formation of ARTESIAN WELLS.

The usual method of boring for this purpose, is to attach the borer, which differs according to the nature

Fig. 193. WELL-BORING.

of the work, to iron rods, which screw together in lengths of from 10 to 20 feet. A circular motion is given to the borer by the workmen above, assisted, when required, by a vertical jumping motion, which causes the boring tool to work its way through the ground. It is usual to begin by digging a circular hole, about 6 or 8 feet deep and 5 or 6 feet wide. In the centre of this hole the boring is carried on by two workmen assisted by a labourer above. The handle of the borer has a female screw in the bottom of its iron shank, into which the boring chisel is fixed, and a wooden bar or rail passing through its socket, with a ring at the top. If the ground be tolerably soft, the weight of the two men bearing upon the cross-bar, and occasionally turning it round, will soon cause the chisel to penetrate; but in rocky strata the chisel is struck down with repeated blows, so as to peck its way, the men frequently shifting their position, so that the chisel or auger may constantly have a fresh place to act upon, by which means the rock is broken and penetrated. This labour is greatly assisted by an elastic wooden pole, placed horizontally over the well, from which a chain is brought down and attached to the ring of the handle. This pole is made fast at one end, by being set in a heap of loose heavy stones; at the other end the workman gives it a slight up-and-down motion, corresponding to the beating motion of the men below, by which means, the elasticity of the pole, in rising, lifts the handle, and thus diminishes the labour of the men. When the hole has, in this way, been opened as far as the length of the chisel will allow, it is withdrawn, and a sort of cylindrical auger, furnished with an internal valve, shewn in section, Fig. 194, is let down for drawing up the dirt and loose stones; the auger being introduced and turned round, the rubbish will pass up through the aperture at the bottom, and fill the cylinder, which is then drawn up and discharged at the top, the valve preventing its escape at the bottom. An iron rod is next attached, and the operation of pecking is proceeded with. The auger is again introduced and the rubbish withdrawn. The necessity of frequently withdrawing the rods, and the continual additions to their length, increases their weight, and renders some mechanical assistance necessary. Three scaffolding poles are, therefore, erected over the pit, and tied together at the top, and from the centre is suspended a wheel and axle, or a pair of pulley blocks, for the purpose of hauling up the rods by means of a fork, Fig. 195, which is brought down under the shoulder, near the top of each rod, and made fast to it by passing a pin through two little holes in the claws. The rods are thus drawn up about 7 feet at a time, and at every haul a fork, Fig. 196, is laid horizontally over the hole, with the shoulders of the lower rod resting between its claws, by which means the rods are prevented from sinking, while the upper length is unscrewed and removed. In attaching and detaching these lengths of rod, a wrench, Fig. 197, is employed, by

Fig. 194

Fig. 195.

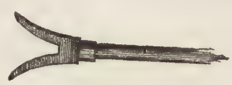


Fig. 196.

Fig. 197.

which they are turned round and the screws forced up to their firm bearing. The first 60 or 100 feet is bored to the diameter of about $2\frac{1}{2}$ inches, and is cleaned out by a gouge of $2\frac{1}{4}$ inches in diameter; the whole is then widened by a chisel, 4 inches in diameter, furnished with a guide for keeping it perpendicular.

The vertical or jumping motion of the tool is often obtained by a windlass instead of the simple plan just noticed. The rods are suspended to the windlass by a rope coiled two or three times round it, and so adjusted, that if the man holds one end of the coil tight, there will be sufficient friction to raise the rods on putting the windlass in motion. On slackening the end of the rope held by the man, the coil becomes loose, and the rods descend with a force equivalent to their weight and the distance through which they have fallen. In this way a regular percussive action is gained by keeping the windlass continually in motion in one direction, while the workman alternately allows the rods to be drawn up a certain distance, and then by relaxing his hold allowing them to fall.

Instead of the arrangement of poles, Fig. 193, it is often desirable to erect a stage over the proposed boring. This stage consists of a stout plank floor, resting on strong puttocks, and well braced together by planks nailed transversely across. In the centre of this floor is a square hole, a little larger than the boring-rods, but not large enough to allow the hook, Fig. 195, to pass through. Wooden trunks or temporary iron pipes are fixed under the boring stage, as guides for the boring tools and permanent pipes, &c. The permanent pipes to be inserted into the bore are joined together and slung ready to be fixed when required. If the bore be through mottled clay, the sooner the pipes follow, the better, as the sand underneath is apt to blow up into the bore-hole, or the clay itself, if not stiff, may choke up the hole. These pipes are either of cast or wrought iron; the latter being generally used for small distances, and the former, being thicker, are used for very deep work, where much driving is required. The lower pipes of the series are usually perforated with small holes, when the spring is in sand; but when water rises from chalk or rock, no perforation is required, and the pipes themselves are only required to keep the hole open. In many cases in and about London, advantage is taken both of the main sand-spring and of the chalk-springs also: the perforated pipes are firmly driven into the former, and smaller pipes and a smaller bore are continued to the chalk. A length of wrought and cast-iron pipe is shown in Fig. 198. The junctions of the pipes have nearly, and, in some cases, quite, an even face on the outside. The cast-iron pipes have generally turned joints and wrought-iron collars, usually flush inside as well as out. The collars are sometimes fixed on the pipes with screws; but when the joints are not turned, they are run together with metal, a plan which shuts out bad water on the outside. The wrought-iron pipes are seldom riveted, but have thin collars soldered on, not quite flush outside, and the melting of the solder previously run in the parts is effected by suspending an iron heater, Fig. 199, down the pipe. The pipes are slung down the well by means of a wooden plug, Fig. 200, with a pin or key passing through it; and this being inserted into the end of the pipe, which is cut reversely, as in Fig. 201, will clearly hold it, and by merely turning round the plug after slacking it, the pipes will be detached. By this plug also the pipes can be driven. This small groove can be used at any depth, and where it is completely out of sight of the workman.

Fig. 198.

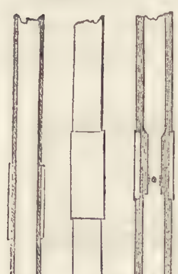


Fig. 199.

Fig. 200.

Fig. 201.

Some of the tools used in boring are shown in the following figures:—

Figs. 202, 203, show an elevation and section of an auger. The tapped socket is to allow the rods to be screwed into it. A usual form of handle for turning round the rods is shown in Fig. 204. The leading nose is for cutting, and there is a valve within the cylinder for preventing the material cut from falling out when the auger is raised. Fig. 205 shows a small auger, with a longitudinal slit, and no valve: it is used for boring through clay and loam. In very stiff clay the slit may be wide; in soft clay, narrow; but in very moist ground this tool cannot be used. The lower figure is a plan, or horizontal section, of this tool. Fig. 206 represents an S chisel, for cutting through rocks, flints, &c. This tool is worked with a vertical motion, and in a circular direction. In boring through sand, or hard ground previously loosened by other tools, a large shell, shown in section, Fig. 207, is used: it contains two valves, opening upwards, one of which is shown in the figure. Fig. 208 is a spring rymer, in which the cutting edges are placed reversely, and the size is regulated by means of the screw and swivel. This tool is used for enlarging a hole. When the pipes are inserted some distance, it is important to widen the bore under them, to allow them to be driven further: this tool is therefore forced down the pipe in a partly collapsed state, springing to its set

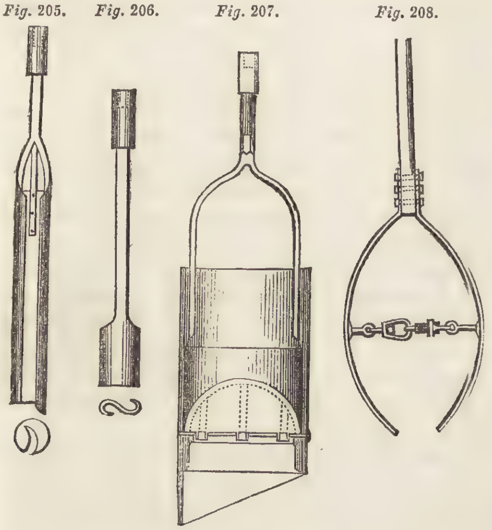
Fig. 202.

Fig. 203.

Fig. 204.

dimension as the softer ground under the pipe is cut away.

Fig. 205. *Fig.* 206. *Fig.* 207. *Fig.* 208.

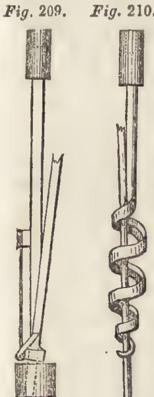


When very soft sand is met with, a tool fashioned like a common lifting pump is used; a vertical up-and-down motion filling the body of the tool with the soft matter. A useful boring tool for hard substances is a hollow cone, Fig. 215, with a spiral winding round it: as the boring goes on, the material accumulates in this cone, and may thus be raised to the working-stage.

In some cases, to ensure the vertical direction of the boring tools, guides are required: these are formed by bolting either to the tools or rods four wrought-iron bars, bent at the ends, so as exactly to fit the hole between the extremities.

One of the greatest difficulties in boring arises from the occasional breaking of the rods. In order to extricate them tools have been contrived. Fig. 209 is a spring latch-tool, in which the forked hinge shuts by the action of a spring; so that when the tool is forced over the knob of the broken rod, as in the figure, the spring shuts the forked hinge under the knob, by which means the broken rod can be raised. When the knob cannot be easily got hold of, a screw, Fig. 210, is used. This tool is also applied when the weight to be raised will not overcome the friction of the screw.

Fig. 209. *Fig.* 210.



Various other tools used in boring are described in works devoted to this branch of engineering, among which we may especially refer to M. Garnier's "Puits Artesiens," 4to. Paris, 1826. An excellent little "Treatise on Well-digging, Boring, and Pump-work," by Mr. Swindell, is published in Weale's Rudimentary Series. The following figures, copied from Garnier's treatise, will convey some idea of the great variety and complication of boring tools.

Fig. 211. *Fig.* 212. *Fig.* 213. *Fig.* 214.

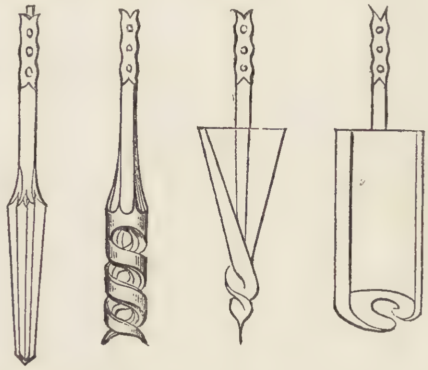
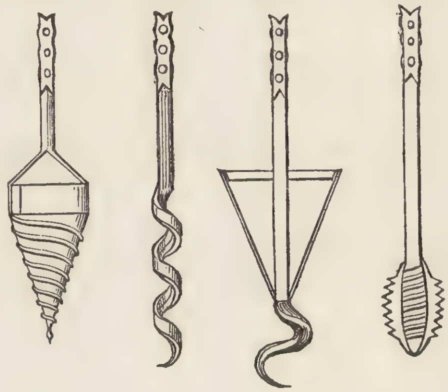


Fig. 215. *Fig.* 216. *Fig.* 217. *Fig.* 218.



Such is a brief notice of the common method of boring Artesian wells. There is, however, considerable variation in the practice of different countries, and even of different districts, according to the geological nature of the place, and the views of the contractor. One of the simplest methods is that practised by the ingenious and industrious Chinese, who have from time immemorial been acquainted with the art of boring the earth for water or for salt brine. In the province of Szu-Tchhouan, on the borders of Thibet, occur a number of salt wells, accompanied by springs of inflammable gas; so that nature not only furnishes the brine, but also the fuel for evaporating the water and extracting the salt. There are several other wells of the same nature in the different districts of this department of Kia-Ting-Fou, and in the other neighbouring districts, situated to the east of the great chain of mountains covered with perpetual snow, which traverses the eastern part of Szu-Tchhouan, from south to north. According to the report of M. Imbert, there are in the vicinity of the town of Ou-Thouang-Khiao several thousands of these salt wells in a space of ten leagues by five. Every person who is tolerably rich takes a few associates with him, and digs one or more wells. The expense of digging a well is from seven to eight thousand francs (280*l.* to 320*l.*, a large sum in China), and the depth is commonly from 1,500 to 1,800

French feet, and five or six inches in diameter. They are usually bored in the solid rock. These people, who accomplish the most difficult undertakings with time and patience, begin by sinking vertically into the bed of earth, usually met with at the surface, a wooden pipe crowned with a hewn stone, perforated with a hole, which, like the pipe, has the same diameter as it is intended to give the well; that is, five or six inches. In this tube there is made to work a steel head of 300 or 400 lbs. weight. This steel is notched at the end, and is a little concave above and round beneath. A workman, by leaping upon the extremity of a lever, the other extremity of which is attached to the steel head, lifts it to the height of two feet, and lets it fall again by its own weight. Some pails of water are thrown in from time to time, to assist the trituration of the substances. The spur or steel head is suspended by a cord, to which is attached a triangular piece of wood, and each time that the lever raises the cord, a second workman, seated near the tube, makes the triangle perform half a revolution, so that the steel head may fall in a different direction. At noon the second workman ascends upon the lever to take the place of his companion. At night two other men take their place. When three inches have been bored, the steel head is withdrawn by means of a pulley, with all the substances with which its upper concavity is loaded. By this mode of boring, the wells are perfectly vertical, and their inner surface highly polished. Beds of sand, coal, &c., are frequently met with. The operation then becomes more difficult, and is sometimes entirely frustrated; for these substances no longer offering an equal resistance, the well loses its verticality; but these cases are of rare occurrence. At other times the iron ring which bears the steel head breaks. When this accident happens at a certain depth, the Chinese know no other means of remedying it than to employ a second steel head to break the first, an operation which may take several months. When the rock is good, an advance of nearly two feet is made in twenty-four hours, so that it may take about three years to dig a well. For a further notice of these wells see SALT.

A method of boring, known in some parts of Europe as the *Chinese system*, is founded on the above method, and consists in suspending the borer by a rope, which, when the tool is worked vertically up and down, imparts by its torsion a sufficient circular motion. In Fig. 219, the tool is shown surrounded by an iron cylinder. The pounded earth or stone collects in the circular space between the tool and the cylinder, by which means they can be brought up to the surface. Different tools are used for different strata, and the usual method of connecting the tool with a number of metal rods, as the work proceeds, is here dispensed with. The chief defect of this simple plan is that the bore-hole is apt to become crooked, so that it is often impossible to sink the pipes required to protect the hole.

Fig. 219.

The great loss of time attending the plan of unscrewing and screwing, pulling up and letting down the rods, is a defect in the common method of boring. An attempt was made to remedy this by an apparatus patented by Beart, in 1844. The rod connecting the boring tool with the workmen above is formed of a tube with water-tight joints: into this tube water is allowed to flow, an upward and a downward current being formed by allowing the water to flow in one direction in the tube, and in the other in the circular space around it. It was supposed that in this way the rubbish loosened by the tool would be brought up to the surface. A portion of the finer material might certainly be got rid of in this way, but not the great bulk of loosened matter; and it is also an objection to the plan, that a large quantity of water is required in places where the very act of boring would seem to indicate a scarcity of that article.

In addition to the examples of remarkable Artesian wells noticed under that head, we may here give a few details respecting the most remarkable work of the kind that has yet been executed. In a letter to the *Times* newspaper, dated 17th August, 1850, Dr. Granville notices the completion of the great Artesian salt spring at Kissingen. He states that on the 12th August last, "the curious spectacle was exhibited of a column of water, 4 inches in diameter, springing with a prodigious force out of the earth to the height of 58 feet, from a depth of 1,878½ feet, spreading out like a graceful palm-tree at its highest point, and forming the finest and most striking jet-d'eau of this kind ever beheld. The water, as clear as crystal, issues from the soil with a temperature of 66° Fahr., charged with 3¼ per cent. of pure salt, at the rate of 100 cubic feet per minute." Only one other such Artesian spring has been completed within the last two years, at Preussich Munden, in which the salt water is drawn from a greater depth, but rises to an elevation of 15 feet only, and is not so intensely salt.

The saline valley in which Kissingen is seated stands at an elevation of 650 feet above the level of the Baltic Sea. The stratification of its rocks, from the surface downwards, as it has been revealed by the successive borings, is extremely simple. The boring implements first went through 1,240 feet of variegated sandstone; then through 350 feet of sandstone of the Vosges formation; next through 150 feet of magnesian limestone (Zechstein); and lastly through 138½ feet of rock-salt, thus reaching a total depth, as before stated, of 1,878½ feet. In the latter, or rock-salt stratum (which is presumed to be 1,000 feet thick), a pure saline source (Soole) is formed, by a solution of the rock-salt in water. This solution has been found to hold not less than 27¼ per cent. of salt; and as there is little likelihood that they would be able to penetrate into the rock beyond 30 feet deeper, to that extent the perforation is to be pushed, and the well completed by the end of this year. At present the supply of water is at the rate of 100 cubic feet per minute, and the force with which this quantity is ejected to the height already stated is

due to a source of almost entirely pure carbonic acid gas, which, having been met with at the depth of 1,680 feet from the surface, at the junction of the gypsum and zechstein, escaped with prodigious force into and out of the Artesian bore-hole, propelling the superincumbent column of water into the air, in the manner above mentioned. In the course of the boring operations, two distinct salt wells were gone through at 222 and 1,240 feet depths, with the respective temperatures of 50° and 66° Fahr., and $1\frac{1}{4}$ and $2\frac{1}{2}$ per cent. of salt. It was under both these wells, at the depth of 1,680 feet, that the great carbonic acid gas stratum was first tapped. This stratum of gas would seem to be equally spread under and throughout the breadth of the valley, imparting its peculiarly piquant and pleasant character to the several mineral springs of this spa. The presence of so enormous a quantity of gas giving rise to an extraordinary commotion in the bore-hole, soon proved an impediment to the further extension of the latter. This induced Inspector Knorr to have recourse to a new and simple contrivance, by which he can arrest the flow of the gas into the Artesian bore, by compelling it to disperse itself through its subterranean recesses, whilst he proceeds downwards with his work of perforation. When the entire work shall have been completed, $3\frac{3}{4}$ cubic feet of brine per minute, free from iron and all other impurities, capable of yielding 50 lbs. of crystallized salt, will be conveyed to the boiling-house for crystallization, carrying with it a temperature of 92° Fahr. But it is intended to limit the whole annual produce of salt from this source to 6,000,000 lbs., which, at the current market price, will add to the revenue of the crown of Bavaria 300,000 florins, after deducting 60,000 florins for yearly expenses of work, fuel, and management. The whole cost of this work will amount to 80,000 florins (6,666*l*.). It was begun in the shaft of an old well, in 1832, from which time, and during a period of 11 years, 800 feet only were bored through the rocks, the operation being often interrupted, and even suspended, from a feeling of discouragement; but, in 1843, Inspector Joseph Knorr, confidently predicating an ultimately successful result, advised the government to resume operations, which have never since been interrupted, either by day or night, and are now about to be completed.

BORON is met with in nature combined with oxygen, forming boracic acid. To separate the oxygen, a portion of boracic acid is heated with potassium in a tube; the oxygen partly combines with the potassium, forming potash, and that portion of the acid which is not decomposed, unites with the potash, forming borate of potash. The mixture is then placed in water, when the borate of potash dissolves, and the boron floats in the shape of a brown powder. Boron is of no importance in the useful arts; its chemical symbol is B.

Boracic acid is found in Thibet and in South America; but the principal supply in Europe is from the volcanic districts of Tuscany, called *Lagoons*, where jets of vapour, called *suffioni*, and of boiling water, charged with boracic acid, are continually

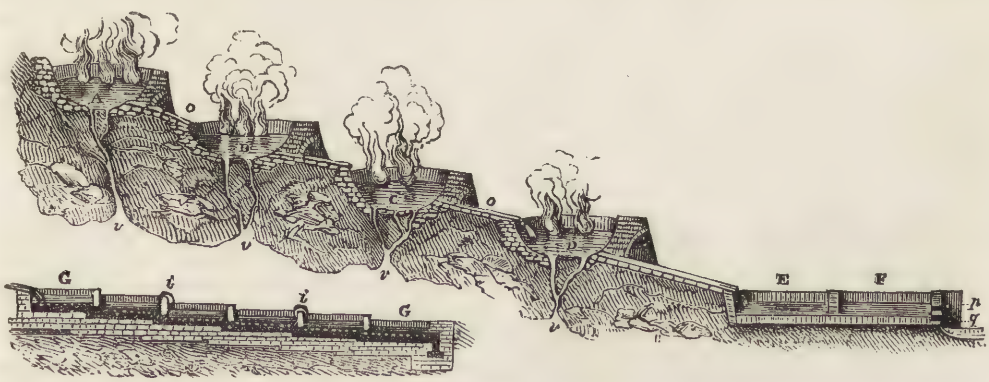


Fig. 220.

issuing from cracks in the ground. Before the manufacture of boracic acid from these sources was undertaken, the district was a positive nuisance, both from the fœtid odour diffused around, and from the accidents which frequently occurred both to man and beast. "As you approach the lagoons," says Dr. Bowring, "the earth seems to pour out boiling water, as if from volcanoes of various sizes, in a variety of soils, but chiefly of chalk and sand. The heat in the immediate neighbourhood is intolerable, and you are drenched by the vapour, which impregnates the atmosphere with a strong and somewhat sulphureous smell. The whole scene is one of terrible violence and confusion:—the noisy outbreak of the boiling element; the rugged and agitated surface; the volumes of vapour; the impregnated atmosphere; the rush of waters among bleak and solitary mountains. The ground, which burns and shakes beneath your feet, is covered with beautiful crystallizations of sulphur and other minerals; its character beneath the surface at Monte Cerboli is that of a black marl, streaked with chalk, giving it at a short distance the appearance of variegated marble."

When the soil exhibits at any spot a high temperature, and vapours of sulphur ascend from it, or any earthquake is felt, a basin more or less deep, according to the locality, is dug there. A column of vapour suddenly issues with considerable force from the

earth; this is surrounded with a wooden chimney, in order to protect the workmen. A suitable form is given to the basin, and the sides are lined with stone. The depth and circumference of such a basin must be in a certain relation to the force of the column of vapour; for, when the depth and surface are too great, and the basin contains too much water, the passage of the vapour is too much opposed, and it often seeks another exit. These eruptions of vapour, however, are not very constant, for the volcano, after being active for several years, may disappear, and seek a new passage, at a distance of from 30 to 60 yards. From the uncertainty of these eruptions, the localities are dangerous to visit without a safe guide; for when the eruption ceases at a certain spot, it is uncertain at what point it will break out: it then frequently forms a subterranean lake near the surface, which breaks through with the weight of a man, and a very dangerous scalding may be the result.

When the walls of the lagoon are finished, the chimney is removed, and water from some source is conducted into the basin, where it is heated to boiling by the ascending vapour, *v*, Fig. 220. The water, of which not much is evaporated, takes up from 1 to $1\frac{1}{2}$, and rarely 2, per cent. of boracic acid. The lagoons are emptied every day, as the amount of boracic acid is not increased by remaining longer, and the solution is conducted from one basin into another, as from A to B, by means of the pipe *o*, until it reaches the reservoir E E, where it deposits its mud, &c., which, not containing any more boracic acid, is removed from time to time, the clear liquor occupying the upper level *p*, and the mud *q*. The clear water is then conducted into the evaporating-pans G G, which are heated by the volcanic steam. In the course of 62 hours, during which the liquor is passed from one pan to another by means of the syphon-tubes *i i*, the solution is sufficiently concentrated, and is conveyed into wooden cooling-vessels, A, Fig. 221, where it is

Fig. 221.

left three days to cool, and deposit crystals of boracic acid. The mother liquor is drawn off into channels B B, and returned to the clarifying reservoir, while the crystals of boracic acid, being first drained in baskets, C, are dried in chambers, D D, heated by volcanic vapour. The crystals are purified by dissolving them in two and a half times their weight of boiling water, and crystallizing a second, or even a third time, if the acid be required very pure.

The dimensions of the lagoons vary from 100 feet in circumference, and 7 feet deep, to 500 and 1,000 feet in circumference, and 15 to 20 feet deep. The large ones enclose from 3 to 15 sources. The construction of these basins required considerable works; terraces had to be built, and hollows filled up, in order to keep the water at the proper level. Rivulets had to be turned out of their course, to prevent their influence on the basins.

In order to heat the evaporating-pans, &c., those sources are turned to account which are not suited to the construction of lagoons. The jets are surrounded in the manner before described, and thence conveyed in subterranean stone passages beneath the evaporating-pans. Each series consists of 14, 18, and 26 pans, 1 foot deep, and 10 feet superficies. The vapour condensed in the passages flows off through an aperture, and the uncondensed vapour escapes through a chimney.

In the year 1846 there were 400 evaporating-pans in operation, each of 10 feet surface, besides which there were several others with diaphragms, arranged in rows, 300 feet in length, in which the water, constantly evaporating, flowed slowly through the different divisions, until it was fit for the cooling vessels. Upwards of 1,200 lbs. of water are evaporated in the course of a day. Until the year 1827, wood was employed for heating the evaporating-pans; but since that time the economical method of heating by the volcanic steam has been adopted, by which a saving of about 10,000,000 francs has been effected. The production of boracic acid in 1846 amounted to 3,000,000 Tuscan pounds. It is stated, however, that the impurity of the acid increases every year, which is probably due to the progressive alteration of the strata, disintegrated by the currents of vapour, and the infiltrations of water. The first products contained from 90 to 92 per cent. of pure crystallized acid; but, according to M. Payen, they now contain from 18 to 25 per cent. of foreign matters.

The composition of boracic acid is

Oxygen	68.78
Boron	31.22
	100.00

Boracic acid is much used in the manufacture of borax, and also in the manufacture of paste for artificial gems; it has also been used with success in the manufacture of enamel.

Borax is a compound salt, formed by the combination of boracic acid with soda. It is first mentioned in the writings of the alchemist Geber, in the tenth century. It has a sweetish taste, and dissolves in 12 parts of cold, or 2 parts of boiling water. It unites with metallic oxides, forming various coloured glasses: with oxide of chrome, it forms an emerald green; with oxide of cobalt, an intense blue; with oxide of copper, a pale green; with oxide of tin, an opal; with oxide of iron, bottle-green, and yellow; with oxide of manganese, a violet; with oxide of nickel, pale emerald-green. The white metallic oxides produce a colourless glass. Borax is very useful as a flux, both to the goldsmith, in soldering the precious metals, and to the brazier, in soldering copper and iron, as it prevents the metal of the flux from oxidizing, and even dissolves any oxide that may have been formed.

BOTTLES. [See GLASS.]

BRANDY. A spirituous product obtained by distilling wine. Its qualities vary with the kind of wine employed. [See DISTILLATION.]

BRASS. An alloy of copper and zinc. The term is commonly applied to the yellow alloy of copper, with about half its weight of zinc, in which case it is called by engineers *yellow brass;* but copper alloyed with about one-ninth its weight of tin is the metal of brass ordnance or gun-metal. Similar alloys used for the *brasses* or bearings of machinery are called *hard* brass, and when employed for statues and medals they are called BRONZE. [See also ALLOY.] In this article will be noticed the alloys of copper and zinc only. In the language of the brass foundry a pound of copper is taken as the standard, and the founder in speaking of the proportions of yellow brass, says "6 to 8 oz. of zinc" ("to every pound of copper" being understood). In the following list of alloys of copper and zinc, the numbers at the beginning of each paragraph denote the ounces of zinc added to every pound of copper.

$\frac{1}{8}$ to $\frac{1}{2}$ oz. This small addition is to enable the copper to cast soundly, which it does not usually do in its pure state. The addition is frequently made in the shape of 4 oz. of brass to every pound or two or three pounds of copper.

1 to $1\frac{1}{4}$ oz. This forms gilding metal for common jewellery. It is made by mixing 4 parts of copper with 1 part of calamine brass; or 1 lb. copper with 6 oz. of brass.

3 oz. Red sheet brass made at Hegermühl, or $5\frac{1}{2}$ copper and 1 zinc.

3 to 4 oz. Bath metal, Pinchbeck, Mannheim gold, similor and alloys with various other names. They resemble inferior jeweller's gold greatly alloyed with copper. Some of them contain a little tin.

6 oz. Brass that bears soldering. Bristol brass is said to be of this proportion.

8 oz. Ordinary brass, less adapted to soldering than 6 oz. as it is more fusible. This is also Emerson's brass, patented in 1781, and the common ingot brass made by simple fusion of the two metals.

9 oz. This proportion is one of the extremes of Muntz's patent sheathing. $10\frac{2}{3}$ oz. is Muntz's metal, or 40 zinc and 60 copper. According to the patentee, any proportions between the extremes, 50 zinc and 50 copper, and 37 zinc 63 copper, will roll and work at the red heat, but the proportion 40 zinc to 60 copper is preferred. The metal is cast into ingots, heated to a red-heat, and rolled and worked at that heat into ship's bolts and other fastenings, sheathing, &c.

12 oz. Spelter solder for copper and iron is sometimes made in this proportion; for brass work, the metals are generally mixed in equal parts.

12 oz. Pale yellow metal, fit for dipping in acids.

16 oz. Soft spelter solder, fit for ordinary brass work, is made of equal parts copper and zinc. About 14 lbs. of each are melted together and poured into an ingot mould with cross ribs, which indent it into little squares of about 2 lbs. weight. Much of the zinc is lost in the fusing and casting, so that the ultimate proportion is less than 16 oz. The lumps are afterwards heated nearly to redness upon a charcoal fire, and are quickly broken up on an anvil, or with an iron pestle and mortar. If the heat be too great, the solder forms into a cake or coarse lumps, and becomes tarnished. At a proper heat it becomes nicely granulated, and remains of a bright yellow colour. It is then passed through a sieve.

16 oz., or equal parts, is one of the extremes of Muntz's patent sheathing.

$16\frac{1}{2}$ oz. Hamilton and Parker's patent Mosaic gold, which is dark-coloured when first cast, but on dipping assumes a beautiful golden tint. When cooled and broken, the yellowness disappears, and the tinge varies from reddish fawn or salmon-colour to a light purple or lilac, and from that to whiteness. The proportions are said to be from 52 to 58 zinc to 50 of copper, or $16\frac{1}{4}$ to 17 oz. to the pound.

32 oz., or 2 zinc to 1 copper. A bluish white brittle alloy, very brilliant, and so crystalline that it may be pounded cold in a pestle and mortar.

128 oz., or 2 oz. copper to every pound of zinc. A hard crystalline metal, differing but little from zinc, but more tenacious. It is sometimes used for laps or polishing discs.

The alloys from about 8 to 16 oz. to the pound are extensively used for dipping, as in the various brass articles used in furniture, &c. The metal is first annealed before it is scoured or cleaned, or the acids, lackers, or bronzes are used.

The ordinary range of good yellow brass, that files and turns well, is from about $4\frac{1}{2}$ to 9 oz. With additional zinc, it becomes harder and more crystalline, and with less, more tenacious. Beyond 8 or 10 oz. the crystalline character of the alloys begins slowly to prevail. Up to this point, they maintain their malleability and ductility.

The red colour of copper merges into that of yellow brass at about 4 or 5 oz., and remains but little altered up to 8 or 10 oz. After this, it becomes whiter.

The addition of zinc increases the fusibility of the alloy, but from the very volatile and inflammable nature of zinc in the furnace, the above named proportions must not be strictly taken, for whatever weight of the two constituents be put into the crucible, there will always be a rapid and to a certain extent uncontrollable waste of zinc.

Brass was manufactured by cementing sheets of copper with calamine or carbonate of zinc, long before the zinc was known in a metallic form, the zinc having been formed and united with the copper without becoming visible as a distinct metal. It is even now not uncommon to use the ore of zinc in making brass. For this purpose the native calamine, after being calcined for a short time, is ground in a mill, the galena contained in it is separated by washing, and it is then mixed at the same time with about a fourth part of charcoal. This mixture is put into large cylindrical crucibles with alternate layers of copper cut in small pieces, or in the form of snot.

Powdered charcoal is then thrown over the whole, and the crucibles are covered and luted up with a mixture of clay, sand, and horse-dung. The old form of furnace was a cone with the base downwards, and the apex cut off horizontally. The crucibles were placed upon a circular grate or perforated iron plate at the bottom, with a sufficient quantity of fuel thrown round them, and a perforated cover made of bricks or clay was fitted to the mouth, which served as a register to regulate the heat. The modern arrangements of a brass foundry are shown in section, in Fig. 222, with the moulding trough *m*, for the sand on one side, and the pouring or spill trough in the centre. [See CASTING.] The furnace is usually built within a cast-iron cylinder about 20 or 24 inches diameter, and 30 or 40 inches high, which is erected over an ash-pit, arrived at through a loose grating on a level with the floor of the foundry. The mouth of the furnace stands about 8 or 10 inches above the floor, and its central aperture is closed with an iron plate *t*, called a *tile*. The inside of the furnace is contracted to

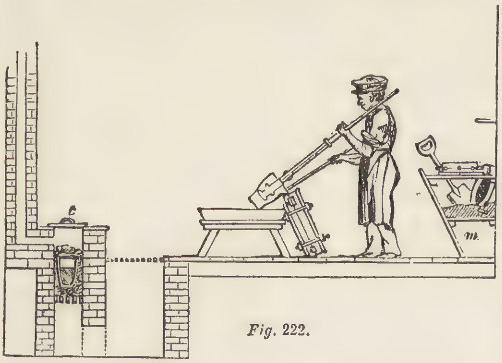


Fig. 222.

about 10 inches diameter by fire-bricks set in Stourbridge clay, except a small aperture at the back, about 4 or 5 inches square, leading into the chimney. There are generally three or four such furnaces standing in a row, and separate flues proceed from each into the great chimney or stack. Each furnace is furnished with a damper. The fuel is hard coke broken into lumps about the size of hens' eggs. The pot or crucible is usually put into the fire soon after it is lighted, with its mouth downwards, by which means the thin edge gets heated and expanded first, and the heat playing within the pot raises it gradually to a red-heat, and prevents the bottom from cracking. The pot is then bedded upon the fuel in its proper position, and an iron cover with a long handle put over it to keep out the small cokes while the man is making up the fire. The charge of metal is then put in, and three or four large pieces of coke are placed across the mouth of the pot; the *tile* is put on the furnace, and the damper adjusted to the proper heat, and the whole is left until the metal is run down. After the alloy is supposed to be formed, (the time varying in different works from 10 to 20 hours, according to the nature of the calamine, and the size of the crucibles,) the heat is increased so as to fuse the whole down into one mass. The tile is then thrown up, and a man striding over the opening grasps the crucible between the jaws of a pair of tongs, and lifts it out of the furnace. The refuse is skimmed off,

Fig. 223. BRASS FOUNDRY.

and another man then seizes the crucible with a pair of tongs, and pours the contents into iron moulds placed in a sloping direction, guiding the stream with an iron rod as in Fig. 223. During this process there is a considerable combustion of zinc, the metal burning with its characteristic bluish white flame, and filling the whole place with dense fumes of white oxide of that metal, or *philosopher's wool*, as it was formerly called from its white colour and woolly texture. To prevent this from entering the lungs, the men tie a handkerchief over their mouths and nostrils during the casting. When the materials are good, a single fusion is sufficient to make good malleable brass; but the finer sorts undergo a second fusion with fresh calamine and charcoal.

If the brass is intended to be rolled into sheets, or made into wire, it is cast into plates between two blocks of Cornwall stone. The lower stone is fixed, and the face made smooth by filling up the recesses of the rough stone with fine sand. The upper stone, prepared in a similar manner, is suspended over the fixed one, the space or mould between the two being limited by iron bars laid on the lower stone, which is a little longer than the upper one, and projects to the front, so as to form a lip or mouth-piece for receiving the metal. The brass, whether in ingots or sheets, solidifies immediately, and can be turned out of the moulds directly the casting is complete.

The most certain method of forming the alloys of copper and zinc, is by the direct union of the two metals in given weights. The usual plan is to thrust broken lumps of zinc beneath the surface of the melted copper with tongs; but there is always a loss of zinc, and in every successive fusion, the more oxidizable metal wastes, so that the original proportion is more and more departed from. When the metals are not well covered with flux, the loose oxide frequently mixes with the metal, giving rise to white coloured stains in the brass, and little cavities filled with oxide of zinc.

Mr. Holtzapffel, in his work on "Mechanical

Manipulation," to which we are already indebted for some of our information contained in this article, has detailed a number of interesting experiments which he tried for ascertaining the best methods of forming alloys of copper and zinc. "The zinc was added to the melted copper in various ways; namely, in solid lumps, in thin sheet hammered into balls, poured in when melted in an iron ladle; and all these, both whilst the crucible was in the fire, and after its removal from the same. The surface of the copper was in some cases covered with glass or charcoal, and in others uncovered, but all to no purpose; as from $\frac{1}{8}$ to $\frac{1}{2}$ the zinc was consumed with most vexatious brilliancy, according to the modes of treatment; and these methods were therefore abandoned as hopeless. I was the more diverted from the above attempts, by the well known fact that the greatest loss always occurs in the first mixing of the two metals, and which the founder is in general anxious to avoid. Thus, when a very small quantity of zinc is required, as for so-called *copper castings*, about 4 oz. of brass are added to every 2 or 3 lbs. of copper. And in ordinary work, a pot of brass weighing 40 lbs. is made up of 10, 20, or 30 lbs. of old brass, and two-thirds of the remainder of copper. These are first melted. A short time before pouring, the one-third of the new metal or zinc is plunged in when the temperature of the mass is such that it just avoids sticking to the iron rod with which it is stirred."

Mr. Holtzapffel next determined to melt the metals on a much larger scale, and in the usual proportions, or 24 lbs. copper to 12 lbs. zinc. Then to ascertain the first loss of zinc. To re-melt a quantity of the alloy over and over again, taking a trial bar each time in order to ascertain the average loss of zinc in each fusion.

24 lbs. of copper, namely, clean ship's bolts, were first melted alone, and the loss was found to be barely $\frac{1}{4}$ oz. on the whole. A similar weight of the same copper was weighed out, and also 12 lbs. of the best Hamburg zinc, in cakes about $\frac{3}{4}$ inch thick, which were broken into about 8 pieces. The copper was first melted, and when the whole was nearly run down, the coke was removed to expose the top of the pot, and when all bubbling had ceased in the copper, the zinc was taken up with the tongs a lump at a time, held beside the pot for a few moments to expel the moisture, and then put into the copper with an action between a stir and a plunge. There was a flare and a low cracking noise as if butter had been thrown in. The zinc was absorbed, and the surface of the pot was clear from its fumes almost immediately. The remainder of the zinc was added a lump at a time, care being taken not to set the copper by inserting the lumps of cold metal too quickly. After each addition, the pot was free from flame in a few moments. A handful of broken glass was then thrown in, the tile replaced, and the whole allowed to stand for about 15 minutes, to raise the metal to the proper heat for pouring, which is denoted by the commencement of the blue fumes of the zinc. The pot was then taken from the fire, well stirred for one minute, and poured. The weight of the brass was 34 lbs. $12\frac{1}{2}$ oz., showing a loss of 1 lb. $3\frac{1}{2}$ oz., or $\frac{1}{10}$th of the zinc, or $\frac{1}{30}$th of the whole quantity. In another experiment, the loss differed from this by only half an ounce, and the mean of the two was $31\frac{1}{4}$ per cent. zinc, or instead of 8 oz. to the pound, it was only $7\frac{1}{4}$ oz.

12 lbs. of each of these brasses were re-melted six times, a bar of $1\frac{1}{2}$ lbs. being taken each time. The loss per cent. of zinc was exactly the same in each of the six experiments, that is, at the sixth melting each bar contained $22\frac{1}{2}$ per cent., or $4\frac{5}{8}$ oz. to the pound of copper. In each case the second fusion sustained the greatest loss, (nearly twofold,) and in the others the loss was pretty much alike.

In forming an alloy of 2.75 copper and 1 zinc, the proportions of which require to be very carefully preserved, as that alloy was found to expand equally with the speculum metal to which it had to be soldered, Lord Rosse found that by employing a furnace deeper than usual, and by covering the metal with a layer of charcoal powder 2 inches thick, the loss each time was the smallest, and almost exactly the 180th each casting. The charcoal dust was renewed by folding it up in paper and throwing it in.

BRAZIL-WOOD. A red dyeing material, obtained from one or two species of *Cæsalpina*, West Indian and South American trees, of the leguminous kind. The term, Brazil-wood-tree, was applied to these trees many years before the discovery of South America; and it is said that the portion of that continent now bearing the name of Brazil was so designated on account of the abundance of these trees found therein. Their importance was soon evident to the Portuguese government, and the name, *Pao de Rainha*, or Queen's Wood, was given to them, in token of the royal monopoly over their exportation. This wood has also the names of Pernambuco, wood of St. Martha, and of Sapan, according to the places which produce it. The tree is of large size, crooked, thorny, irregular of growth, with small leaves, and fragrant red flowers. The bark is exceedingly thick, and when removed, the heart of the tree, which is the only useful portion, is of comparatively small size. The wood is of a pale red when first cut, but the colour becomes deeper by exposure to the air. The thickest pieces, with a close grain, are the best. Boiling in water extracts the whole of the colour, and, if continued long enough, produces a very fine red. This colour is, however, very fleeting, and is used with alum, and tartar, and with various other mordants, which vary the shades of red considerably. The colouring matter of Brazil-wood is easily affected by the action of acids, producing an orange or yellow colour, which is durable. It is also sensitive to the action of alkalies, which produce various shades of violet and purple; but these are not to be depended upon, being, in general, very fleeting.

The colour known in the trade as false crimson (to distinguish it from cochineal-red), is given to silks by means of Brazil-wood; the silk being first boiled with twenty parts of soap per cent., then

alumed, and refreshed at the river, and finally passed through a bath charged with more or less Brazil-wood, according to the colour required. Stronger colours are gained by first giving a ground of annotto to the silk, or by adding logwood to the brazil-bath, with a little alkali, if necessary. Nicaragua and peach-wood are also species of cæsalpina. Red ink is made by boiling two ounces of Brazil-wood for a quarter of an hour in a pint of water, and adding a little gum and alum.

The colouring principles belonging to Brazil-wood are known to chemists as brasiline and brasileine; the first being the colouring matter of the wood, and the second, a colourless substance, which appears to pass into the proper colouring matter by oxidization.

Within the last ten years, Brazil-wood has been in some measure superseded by a wood imported from Africa, which yields a finer and more permanent colour. It is called by the dyers *cam-wood.* The tree from which it is obtained grows at Sierra Leone, and in the interior of Africa, and is believed to be that known among botanists as *Bahia nitida.* In consequence of this, and of the vexatious monopoly on Brazil-wood, the importation of the latter has greatly declined, and is now inconsiderable. By the recent alteration in the tariff, it is admitted duty-free.

BRAZING. [See SOLDERING.]

BREAD. Many of the useful arts seem to have originated in the necessities of man's nature, which led him to use a great proportion of his food in a manner peculiar to himself, and thus raised him above the lower animals in not devouring it raw. When the difficulties of the subject are considered, it is not surprising that some nations regarded the useful arts as of divine origin; for in the absence of science, and of that spirit of inquiry which scientific researches so eminently encourage, what can be more difficult than the first step in the art of bread-making? It was, indeed, a great discovery in the early history of the world, that by moistening grain, and then subjecting it to the action of heat, a compact cake of food could be formed, containing within a small compass a large amount of nutrition, capable of being kept for a length of time, and yielding when masticated an agreeable relish to the palate. The second step was also a difficult one, namely, the reducing of the grain to powder before moistening it. This was done by pounding or *braying*[1] it between two stones, or in a mortar, a method still practised by some rude nations. But the third step must have been most difficult of all, namely, that of exciting fermentation, or combining with the bread a gaseous body identical with that which gives the foaming appearance to ale, and the sparkling appearance to champagne. The effect of this process is as remarkable as the process itself, for instead of a heavy, hard, tough, dull, indigestible mass, a light, porous, elastic food is produced, more agreeable to the palate, and more conducive to health. The two forms of bread here described are still in use, the one being the common sea-biscuit [*vide* BISCUIT], and the other the wheaten loaf. In well-made bread, the effect of the gas disseminated throughout its substance is remarkable. It forms the bread into vesicles, which are arranged in a succession of layers, one above another, perpendicular to the crust; a sort of structure called by the bakers *piled bread,* and regarded as a sure test of the success of the batch. The increased facility of digestion of well piled bread is thus shown by Dr. Colquhoun:[2]—If a portion of such bread, well baked and thoroughly cool, be pressed between the fingers, it will crumble readily into powder, and if placed in hot water, it will immediately swell, disintegrate, and admit of being easily diffused through the liquid. Whereas, unpiled bread pressed between the fingers remains a solid cohesive mass, and in hot water does not soften further than to become a permanently tough mass of dough.

The term loaf is said to be derived from the Anglo-Saxon *hlif-ian,* to raise or lift up, the dough being *loaf,* or raised by a fermenting substance named *leaven,* (Latin *levo,* French *lever,* to lift.) Hence the term *leavened* and *unleavened* bread. The word *dough* is said to come from the Anglo-Saxon *deawian,* to wet or moisten, so that *dough* or *dow* means wetted. Now, if a mass of dough be left to itself for a sufficient time, it will pass spontaneously into a state of fermentation or incipient decomposition, which will generate carbonic acid within it, and give the bread baked from it a lightened vesicular texture. A more speedy method than this is adopted in practice, but if a small portion of old dough in a state of active fermentation be diffused through a mass of fresh dough, the process of fermentation therein will be greatly accelerated. When this is done, the mass is said to be *leavened,* and the fermenting dough thus added is the *leaven.* In the earliest record of the history of man, we find that cakes and unleavened bread were made by Abraham. But leavened bread was well known in the time of Moses, for we find (Exodus xii. 15) a prohibition against the use of it during the passover. Hence it has been supposed that the use of fermented bread originated in Egypt. The Greeks refer the invention to the god Pan. The Romans derived it from the Greeks, and until about 200 B. C., when bakers were first established in Rome, the term "pulse-eating nation" was applied to the Romans by way of reproach. From Rome the art of making leavened bread was slowly introduced among the northern nations, and even at the present time, in the northern countries of Europe and Asia, fermented bread is seldom used except among the higher classes. In many parts of Sweden rye cakes, as hard as wood, are baked twice a-year, and form the common bread of the lower orders. And in Scotland, up to a recent period, barley bannocks and oaten cakes were the ordinary bread of the people.

(1) According to Horne Tooke, the word *bread* is derived from *brayed* grain, from the verb to *bray,* or pound in a mortar, the ancient method of making flour.

(2) Chemical Essay on the Art of Baking Bread, Annals of Philosophy, Vol. XII. New Series, 1826.

The only substance adapted to the making of good fermented bread is the flour of wheat, a grassy plant, the *triticum* of botanists. It is more extensively cultivated than any other plant, and like man, seems to adapt itself to nearly every climate. Excellent crops of it have been raised in the latitude of 60° N., and it is cultivated in the East Indies within the limits of the torrid zone. Its original habitat is unknown. It improves in quality as it advances south, within certain limits. Thus, the wheat of Essex and Kent is of better quality than that of East Lothian and Berwickshire. The French wheat is better than the English, the Italian better still, but the wheat of Barbary and Egypt is probably the best in the world.

The essential constituents of wheat flour are *starch*, also called *farina* or *fecula*, *gluten*, and a little *sugar* and *albumen*. According to Vogel's analysis, 100 parts of wheat flour contain starch 68 parts, gluten 24, gummy sugar 5, and albumen 1.5; but these proportions vary with the goodness of the wheat.[1]

The STARCH of wheat flour is very nutritive. It is a white, crisp, crystalline substance, insoluble in cold water, but forming a thick paste with hot water. When roasted till it becomes brown, it is rendered soluble, and acquires the properties of gum. When boiled for a long time in very dilute sulphuric acid, it is converted into a species of sugar.

GLUTEN or GLUTINE can be separated from wheat flour by tying up a portion of flour in a coarse cloth, and kneading it under a stream of water till the starch and soluble matters are washed out, and the water runs off clear. The gluten left in the cloth is a grey, viscid, tenacious, insoluble mass. When moistened, it undergoes a species of fermentation. Bubbles of gas separate from it, and in about ten or fourteen days it acquires the smell and taste of cheese. Gluten is a mixture of vegetable fibrine and a small quantity of a peculiar matter containing nitrogen called *gliadine*, to which its adhesive properties are due. Gliadine is gluey and adhesive, insoluble in water, and when dry, hard and translucent like horn. The fibrine of other grain does not contain gliadine. Barley and oatmeal yield no gluten, but these and other vegetable substances, such as potatoes, and even turnips, can be made into fermented bread by the addition of gluten or of wheat flour. 2 parts of wheat flour and 1 part of boiled potatoes form an agreeable bread. The starch of potatoes is a very beautiful substance; mixed with a little gum tragacanth, it is often sold as Indian arrow-root.

(1) Mr. Edlin, in his "Art of Bread Making," London, 1805, found in one pound of good wheat,

Bran	3 oz.	or $\frac{1}{5}$
Starch	10	or $\frac{2}{3}$ nearly..
Gluten	0 ,, 6 drachms	or $\frac{1}{21}$
Sugar	0 ,, 2	or $\frac{1}{64}$
Loss in grinding and reducing the flour to starch	2	
	16 0	

The albumen appears to have escaped his analysis.

The small proportion of SUGAR in wheat flour, enables it to ferment on being mixed with water, without the addition of yeast. Thus the dough of wheat flour by spontaneous fermentation becomes converted into leaven. In the first part of the process, the fermentation is entirely confined to the sugar; and here the process ought, if possible, to be arrested; but as this is not always possible, the vinous fermentation passes into the acetous, and a portion of vinegar is formed. It was formerly supposed that the fermentation of the dough made from wheat flour was peculiar to itself, and it was hence called *panary fermentation.* This is now known to be a mistake; for if the sugar be previously washed out of the flour, there will be no fermentation. During the rising of the dough, carbonic acid is formed at every part, and is prevented from escaping by the gluten, which forms a kind of adhesive web. The formation of the gas causes the dough to swell in every direction, and the particles of starch to separate, in which condition the process is arrested by the heat of the oven, so that when the bread is cut open, it is piled or full of cavities, each of which in the dough contained a globule of carbonic acid.

If the milky water obtained by washing wheat flour in order to separate its gluten, be allowed to repose for a few hours, it becomes clear by depositing a quantity of starch. If this liquid be boiled, it becomes turbid from the production of a flocculent precipitate, which, when collected, washed, dried, and purified by boiling with ether, is found to have the same composition with animal albumen. [See ALBUMEN.]

In the preparation of wheat for the manufacture of bread, the ground grain is usually separated into three parts, the *flour*, the *pollard*, and the *bran*. The bran is the outer husk of the grain, and is not used as food except for horses. The pollard is the part next the husk, and is coarser and darker than the flour, which forms the interior or central portion of the grain. The flour forms on an average about three-fourths of the wheat ground. In the preparation of wheat, the miller forms different kinds of flour, some of which are very fine and white, otners coarse and unpalatable. The white flour is pleasing both to the eye and to the taste, and in London there is so strong a prejudice in favour of white bread, that scarcely any bread which is not white will find a sale. Hence the baker resorts to various methods of bleaching, which will be noticed hereafter. There are, however, seven distinct kinds of flour or meal produced in England from a quarter of wheat, namely:—

Fine flour	5 bushels	3 pecks.
Second flour . . .	0 ,,	2 ,,
Fine middlings . .	0 ,,	1 ,,
Coarse middlings .	0 ,,	0.5 ,,
Bran	3 ,,	0 ,,
Twenty-penny . .	3 ,,	0 ,,
Pollard	2 ,,	0 ,,
	14	2.5

Thus wheat by being ground into flour almost doubles in bulk. During the bolting, a fine white gritty substance, called *sharps*, is obtained. This is the finest portion of the grain, and is sold to the biscuit bakers; or being ground again, it forms the finest flour.

Now it is important to inquire whether the practice of consuming none but the whitest bread, even supposing it to be pure, is conducive to health and economy. In the preparation of wheat, the miller cannot entirely separate the bran, and hence a portion of it is ground up with the flour; but by sifting he separates it more or less completely, and thus obtains his seconds, middlings, &c. The *whole meal*, as it is called, of which brown household bread is made, consists of the entire grain ground up together, and used as it comes from the millstones; it therefore contains all the bran. By rejecting the bran, as we do when the finest flour only is used for bread, we actually lose a large amount of nourishment of the most important kind.

If we examine the composition of the two portions of the grain, the fine flour and the bran, we shall be able to ascertain how much they respectively contain of the several constituents of the animal body. Professor Johnston has put the subject into a practical form, by showing the value of whole meal or household bread, in forming and sustaining the three principal solids of the human body—fat, muscle, and bone.

1. *The fat.* Of this ingredient 1,000 lbs. of

Whole grain contribute	38 lbs.
Fine flour	20 „
Bran	60 „

So that the bran is much richer in furnishing the materials of fat than the interior part of the grain, and the whole grain ground together is richer than the finer part of the flour, in the proportion of nearly one-half.

2. *The muscular matter.* 1,000 lbs. of whole grain, and of the fine flour, contain of muscular matter respectively—

Whole grain	156 lbs.
Fine flour	130 „

So that of the material out of which the animal muscle is to be formed, the whole meal or grain of wheat contains one-fifth more than the finest flour. For maintaining muscular strength, therefore, it must be more valuable in an equal proportion.

3. *Bone material and saline matter.* 1,000 lbs. of bran, whole meal, and fine flour, contain respectively—

Bran	700 lbs.
Whole meal	170 „
Fine flour	60 „

So that in regard to this important part of our food, necessary to all living animals, but especially to the young during their growth, the whole meal is three times more nourishing than the fine flour.

Taking the three essential elements of a nutritive food thus existing in wheat, and comparing their respective amounts in the whole meal and in the fine flour, we find that on the whole, the former is one-half more valuable for fulfilling all the purposes of nutrition than the fine flour. "It will not be denied," says Professor Johnston, "that it is for a wise purpose that the Deity has so intimately associated in the grain the several substances which are necessary for the complete nutrition of animal bodies. The above considerations show how unwise we are in attempting to undo this natural collocation of materials. To please the eye and the palate, we sift out a less generally nutritive food—and to make up for what we have removed, experience teaches us to have recourse to animal food of various descriptions. It is interesting to remark, even in apparently trivial things, how all nature is full of compensating processes. We give our servants household bread, while we live on the finest of the wheat ourselves. The mistress eats that which pleases the eye more, the maid, what sustains and nourishes the body better."

It has been found by Majendie and others, that animals died in a few weeks when fed only upon fine flour, but lived long upon whole bread. Thus, the coarse bread given to prisoners is the best they could have, for being restricted from all other food, there would not be sufficient nutriment in fine white loaves to sustain life for a length of time. The nutritive properties of bran are exhibited in its effects in fattening pigs, &c., and thus, this apparently woody and useless material is found to produce valuable results.

Wheat, taken in the natural mixture found in the whole seed, is the most nutritive of all vegetable substances, and is therefore, when at a moderate price, quite as economical as some of the cheaper kinds of grain. It is only when wheat is very scarce, and consequently very high priced, that substitutes are sought for it in inferior articles. According to Liebig, Boussingault and others, 107 parts of wheat are equal in nutritive power to 111 of rye, 117 of oats, 130 of barley, 138 of Indian corn, 177 of rice, 894 of potatoes, and 1,335 of turnips.

The process of machinery by which wheat grain is converted into flour next demands attention. The ordinary flour-mill is an object with which we are all familiar, and is generally associated with much that is picturesque and beautiful. If the power employed be water, the mill is usually situated in a valley enriched by some considerable stream, and luxuriant in vegetation—the favourite resort perhaps of the angler, and the chosen sketching ground of the landscape-painter, to whom "an over-shot mill" seems an especial object of delight. Whether the power employed be steam, wind, or water, the machinery of a flour-mill is much the same but as we have recently explored a water-mill, seated in one of the picturesque spots above referred to, the description of the machinery will be taken from thence, with such trifling variations as our observation of other flour-mills may suggest.

The moving power in mills of this description is a broad and heavy wheel, occupying the whole of the space between the walls of a chamber in the

basement through which the stream rushes. This wheel may be what is termed *undershot*, *overshot*, or *balance*, but our present description applies to an undershot wheel. The circumference is provided with a number of projecting boards called *float-boards*, which being exposed to the action of a running stream, (generally increased by an artificial fall,) cause the wheel to be driven round, and thus to communicate motion to all the rest of the machinery. The overshot and balance wheels are close boarded, or close-soled as it is called, round their circumference; that is, they are closed in the spaces between the float-boards; but the undershot wheel is open.

When the wheat is brought in sacks to the mill, it is hoisted from the wagon to an upper floor, whence, in due time, and being properly cleansed, it descends to the mill-stones by means of a hopper, the quantity being regulated so that an equable flow of grain shall be continually supplied. The mill-stones are two large circular stones placed one above the other, but not quite close enough to touch. The lower is immovable, but through its centre the spindle rises on which the upper stone revolves. Motion is given to this spindle, and consequently to the upper stone, by cog-wheels below, connected with the great water-wheel or first mover. Through the hole in the centre of the upper stone the corn is admitted by means of a funnel. The surfaces of the stones are plane or flat, but they have a number of shallow furrows cut in them for the passage of the flour, which is forced out on all sides after it has been fully pulverized by the action of the stones. But it does not escape to any great distance, for a large wooden case covers in the stones while they are in

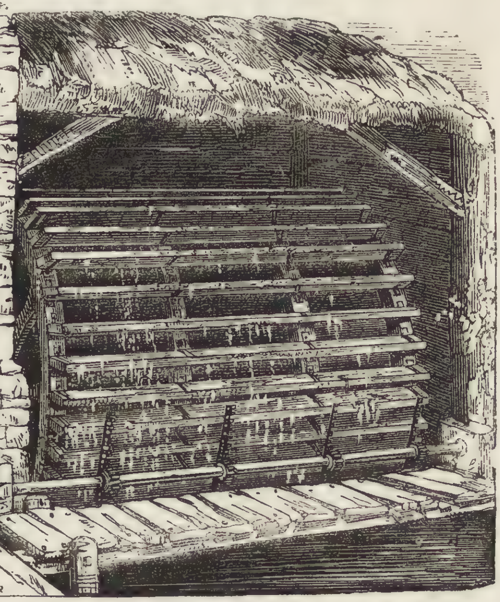



Fig. 224. DETAILS OF A FLOUR MILL.

action, and confines the flour to a certain space of the floor of the room. Within this space there is a small opening in the floor, through which, as the case becomes full, the flour rapidly falls, and is conveyed by a spout to its destined bin. The channels or furrows in the mill-stones are arranged in a particuliar order, there being frequently eight long ones from the centre to the circumference called master-furrows, and twenty-four shorter ones, arranged in the manner here represented. Each furrow is cut perpendicularly on one side and obliquely on the other, which gives it a sharp edge. Both stones are cut exactly alike; hence it follows, that when the upper one is turned over, and its position reversed, the sharp edges then come opposite each other and when in motion, they meet, and cut the corn to pieces. The plane parts of both stones are called "lands."

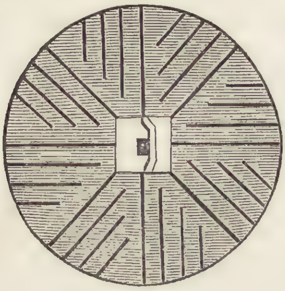


Fig. 225.

The bedding of mill-stones is a matter of great importance, and the requisite firmness is usually secured by a cast-iron frame-work, fitted with screws, and supported by the cross timbers of the flooring of the mill. A patent was taken out in 1821 for fixing the stone in a cast-iron frame, embedded in plaster-of-Paris, and of one uniform strength, but the plan has not been generally adopted. Mill-stones are of various materials, but those in general use for grinding wheat are made of a very hard siliceous stone imported from France, the technical name being *burr* or *buhr*. This stone is so porous that it sometimes requires to be filled up in parts, with a composition of alum and grit; and yet it is so hard, that a pair of stones in full work will last twenty or thirty years. The mill-stone is not one solid piece, but is made up of a number of pieces, cemented by plaster-of-Paris, and secured by iron hoops round the circumference. Burr-stones are a rare geological formation, and are found in abundance only in the mineral basin of Paris, and some neighbouring districts. The finest quarry of them is near La Ferte sous Jouarre.

There is much difference of opinion as to the best size of mill-stones, and the velocity which should be employed. The generality of mill-stones are from 4 to 5 feet in diameter, and make from 80 to 100 revolutions in a minute; but the tendency at present is to diminish their size, and increase the velocity of their revolutions. Great velocity generates heat, which with the large stones is very injurious to flour, and produces a condition of that article known to millers as *greased*, indicated by a soft and slippery feeling; but it is found that with small stones, although the velocity be great, the corn does not remain long enough under tnem to arrive at this condition. The only disadvantage of the small stones seems to be, that, in dressing the flour prepared from them, more middlings or sharps are made than by the large ones. Where meal of a very superior quality is required, a *sheeling-machine* is added to the rest of the apparatus, and the wheat is first passed through a cylindrical sieve, to remove all impurities, and then between a pair of mill-stones, called sheeling-stones, which remove nearly all the bran without breaking the corn. These stones are not cut into channels, nor are they brought so near together as the grinding-stones. The sheeled wheat is received into a sieve, and afterwards into a fanning-machine; and when, by the action of these, the bran is entirely separated, it is then ground into flour, which is of remarkable whiteness and purity, although for the purposes of nutrition it is not improved by this process. Without reference to this refined method, the ordinary fine flour is produced by wheat of the best quality, well and perfectly ground; that is, having the bran and the flour completely separated, without reducing the bran to such small particles as to allow of its going through the dressing-machine with the flour. The miller's own experience can alone guide him in grinding well, and keeping his millstones in proper order. The evils of over-grinding and under-grinding have both to be guarded against: the former injuring the flour; the latter subjecting the miller to loss. Damp wheat clogs and impedes the stones, and leaves no remedy but fresh dressing them; therefore, if dryness cannot be attained by natural means, kiln-drying must be adopted, although the wheat is deteriorated thereby.

Wheaten flour, in common with every other article of commerce, is subject to adulteration; but, fortunately for the consumers, the adulterating material is not unwholesome. This is generally bean or pea-flour, and is not used in sufficient quantity to make it of serious importance; while in some of the more extensive mills, we are assured, adulteration is unknown.

Flour is *dressed*, or separated from the bran, by means of a *dressing-machine*. This is an ingenious contrivance, in the form of a long hollow cylinder, placed in a slanting position, and covered internally with wire-cloth, of varying degrees of fineness. Externally, the framework of the cylinder is composed of longitudinal and circular ribs of wood, placed at regular distances from each other. Inside the cylinder is a revolving reel, with hair brushes attached, Fig. 226. These extend the whole length of the cylinder, and, as they revolve, brush against the wire-cloth lining of the cylinder, agitating and driving through its interstices the finer portions of the meal, which had been previously taken from the mill-stones in sacks, and raised by means of sack-tackle to an upper floor, whence it now gradually descends through a spout into the dressing-machine. The finest of the flour will go through the upper end of the cylinder,

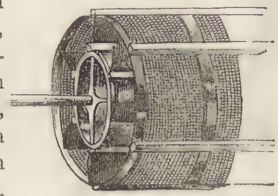


Fig. 226.

because the finest wire-cloth is placed there; the next finest through the next division; then the middlings, through the next division; and, finally, the pollards, or sharps, through the last division; while the bran, being too coarse to go through any of the divisions, is discharged at the lower end of the cylinder. The whole of this apparatus is enclosed in a large box, to prevent the waste of flour which would otherwise take place. The lower part of the box is divided into compartments, into which the flour falls, according to its several degrees of fineness, and can thus be kept distinct; but these divisions can be shifted at pleasure, so as to vary the qualities of the flour. When the meshes of the cylinder become clogged, as in the course of time they always do, a brush, acted upon by the machinery, is applied to the exterior, and clears it in a much shorter time than it could be done in the old way by hand. The pinion for turning the dressing-machine should be made to revolve in either direction, because the hair of the brushes becomes bent, and worn on one side, requiring to have the action reversed.

The dressing-machine is a great improvement on an earlier method, called the bolting-mill, which is not, however, out of use. Both machines are employed in the flour-mill lately visited by the writer. The bolting-mill, Fig. 227, is a long reel, covered with a peculiar kind of cloth, somewhat similar to that of which shrouds are made. This reel, with its cylindrical cover of cloth, revolves rapidly, and in so doing comes in contact with a number of bars of wood, called *beaters*, striking

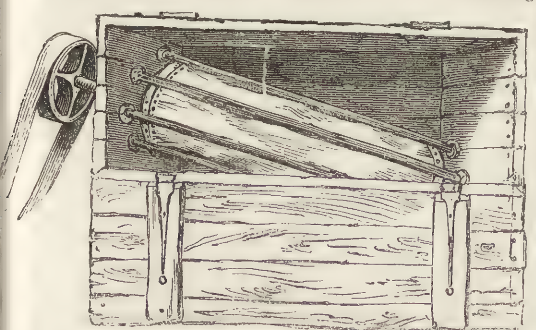


Fig. 227.

against them with considerable force, and thus forcing the finer portions of the meal within the cloth to escape through its substance. The bolting-cloth is, in fact, a cylindrical sieve, and its chief defect is that, in sifting the meal, it produces only one quality of flour, instead of several, as in the dressing-machine. On this account it is necessary to have bolting-cloths of different degrees of fineness, and to change them according to the sort of flour required. The bolting-cloth is terminated at each end by a broad piece of white leather, neatly sewed on, with a drawing-string round it. The leather answers the double purpose of strengthening the bolting-cloth, and allowing the miller to fasten it securely to the reel. The bolting-mill, like the dressing-machine, is placed in an inclined position, and the refuse falls down to the tail end. This apparatus is also enclosed within a box, to prevent waste of flour.

From the several varieties of flour obtained by the above processes, three kinds or classes of bread are usually manufactured in Great Britain: 1. Wheaten bread, or *firsts*, which is made of the finest flour; 2. Household bread, or *seconds*, which is somewhat coarser; 3. Brown bread, or *thirds*, which is made of flour of various degrees of coarseness. With wheat of the same quality, the coarseness or fineness of the flour depends, as already noticed, on the dressing, or separating of the husks of the wheat, after being ground. For making firsts, the flour is entirely separated from the bran or husks; in the other descriptions, the bran is not entirely removed, but the coarse broad bran is separated from the coarsest flour.

The bake-house ought to be a large room, with a dresser on one side, with suitable shelves above it. On another side is the kneading-trough, which is about 7 feet long, 3 feet high, 2½ feet broad at the top, and 19 inches at the bottom, with a sluice-board, to pen up the dough at one end, and a lid to shut down. The third side contains a copper, capable of holding 3 or 4 buckets of water. The oven occupies the fourth side: this may be 3 or 4 feet high, with an arched roof, and a brick or stone floor, furnished with a door to shut close. The fire-place is usually at one side, and the heat is communicated by winding the flue round the oven. A portion of the fire is also used for heating the copper. The proper temperature of the oven for baking is about 450°: the bakers, however, do not use a thermometer, but judge of the heat by throwing flour on the floor; if it soon blackens, without taking fire, the heat is judged sufficient..

The utensils of the bakehouse consist of, 1. The *seasoning-tub;* 2. The *seasoning-sieve*, made of hair, or of tinned iron, with holes drilled through it; 3. *Wire sieves*, for sifting the flour; 4. A *bucket;* 5. A *bowl;* 6. A *spade* or *shovel;* 7. A *salt-bin*, placed near the oven; 8. A *yeast-tub;* 9. A *dough-knife*, about the size of a large carver, with a round blunt point; 10. *Scales* and *weights;* 11. A *scraper*, made like a hoe, fixed in a short wooden handle, and used for scraping the dough off the trough and moulding-board; 12. Four or five *peels*, of different sizes; the peel being a sort of shovel, with a long handle, used to set the bread in the oven, and also to take it out; 13. *Tins*, or *iron plates*, for baking buns, pies, puddings, &c. on; 14. Coarse thick *flannels*, for covering up the dough and the bread; 15. A *rasp*, or broad flat file, with a wooden handle, for rasping burnt crust off bread; 16. The *scuttle* or *swabber*, a quantity of wet netting at the end of a pole, about 8 feet long, for cleaning the oven, preparatory to setting the batch; 17. *Set-ups*, or four-sided oblong pieces of beech, for placing on both sides, and at the back and front of the oven, to keep the loaves in their places; 18. The *rooker*, a tool resembling the letter L, fixed in a wooden handle, for the purpose of drawing out the ashes from the oven; 19. A *hoe*, which is used for a similar purpose.

At the time when Dr. Colquhoun's essay was written, the following appears to have been the practice of the London bakers in the manufacture of bread by means of yeast-fermentation. The baker generally takes a portion only of the water which he intends to employ in making the required quantity of dough. The temperature of the water varies from 70° to 100°, and contains a portion of the salt necessary to give the bread its proper flavour.[1] Yeast is next mixed with the water, and then a portion of flour is added, always less than the quantity intended for the finished dough. The mixture is covered up and left in a warm situation. The substance thus set apart is called the *sponge:* its formation and covering-up is termed *setting the sponge,* and according to the amount of water in the sponge, with reference to the whole quantity used in the dough, it is called *quarter, half,* or *whole sponge.* In about an hour, the mixture thus set apart begins to ferment. It swells out, and heaves up, evidently in consequence of the generation of some internal elastic fluid, which in this instance is always carbonic acid gas. If the sponge be of a semi-fluid consistence, large bubbles of gas soon force their way to its surface, where they break and dissipate in rapid succession. But where the sponge has the consistency of thin dough, it confines the gas within it until it dilates equably and progressively to nearly double its original volume, when, no longer capable of containing the pent-up air, it bursts and subsides. This process of rising and falling might be carried on actively and frequently during many hours, but experience has taught the baker to guard against allowing full scope to the energy of the fermentation. He generally interferes after the second or third dropping of the sponge, and were he not to do so, the bread formed from this dough would be sour to the taste and smell. At this period, therefore, he adds to the sponge the remaining proportions of flour and water, and salt, which may be necessary to form the dough into the required consistence and size; and next incorporates all these materials with

Fig. 228. THE KNEADING-TROUGH.

the sponge by a long and laborious course of kneading, Fig. 228. When this process has been continued until the fermenting and the newly added flour have been intimately blended together, and until the glutinous particles of the flour are wrought into a tough and elastic dough, so that it will receive a smart pressure of the hand without adhering to it, the kneading is for a time suspended. The dough is left to itself for a few hours, during which time it continues in a state of active fermentation throughout its whole extent. It is next subjected to a second but much less laborious kneading, the object of which is to distribute the gas within it as equably as possible throughout the whole mass, so that no part of the dough may form a *sad* or ill-raised bread from the deficiency of gas, or be too spongy from its excess. After the second kneading, the dough is weighed out into the portions requisite to form the kinds of bread desired. These portions of dough are shaped into loaves, and once more set aside for an hour or two in a warm place. The continued fermentation soon generates a sufficient quantity of carbonic acid to expand each mass to about double its former volume. They are now considered fit for the fire, and are finally baked into loaves, which when they quit the oven are nearly twice as bulky as when they had entered it. The generation of the due quantity of gas within the dough is necessary before placing it in the oven, because as soon as the dough is exposed to a great heat, the process of fermentation is arrested, and it is only the previously contained gas, which expands by the heat throughout every part of each loaf, that swells out its whole volume, and gives it the piled vesicular structure. Thus a well-made, and well-baked loaf, is composed of an infinite number of cellules, each of which is filled with carbonic acid gas, and lined with or composed of a glutinous membrane; and it is this that communicates the light, elastic, porous texture to the bread.

The next process is that which is actually practised at the present day. It is given in Mr. Charles Knight's excellent series of works, published under the general title of "Guide to Trade." The number entitled "The Baker" has furnished us with several useful hints in the preparation of this article.

Take a peck of potatoes, (about 8 lbs.) and boil them with their skins on; mash them in the seasoning tub, add 2 or 3 quarts of water, about the same quantity of patent yeast,[1] and 3 or 4 lbs. of flour. Stir them well together, and cover the mixture up close with a sack, and let it stand for 6 or 12 hours, when it will have become what is called *ferment.* Then empty or sift a sack of second

(1) This appears to be a mistake, for if the salt were added at this early stage, it would interfere with the process of fermentation. See the modern process next described.

(1) This is prepared as follows:—Half a pound of hops is boiled in two pailfuls of water till the liquid is reduced to one pailful; the decoction is then strained, and when sufficiently cool, half a peck of malt is added. The hops strained off are again boiled in the same quantity of water until it is reduced one-half; the hot liquid is strained into the former. The hops are boiled the third time, and the liquor strained into the former. When the whole has cooled down to blood heat, two quarts of patent yeast are added. Brewer's yeast will not answer. A little flour is adde to the malt and hops, but this may be dispensed with in summer. In this way 5 gallons of good yeast are prepared. It is ready for use the next day. It occupies 7 or 8 hours in the making, but gives very little trouble to the baker.

flour into the trough, and take a little less than one quarter of the sack of flour, and pin or block it up to one end of the trough with the pin board. Then bring the seasoning tub with the ferment in it to the trough, pour in a sufficient quantity of warm water, (in summer, cold,) stir up the mixture with the hands, and mash any lumps of potatoes that may be in it. Next, strain it through a sieve, to separate the skins of the potatoes; then pour the mixture liquor into the flour which had been previously pinned or blocked up at one end of the trough, and mix it well into the flour with the hands. Sprinkle a little flour over the top, and let it stand 5 or 6 hours, during which time the sponge will have risen twice. The first rising is suffered to break and go down. In about an hour or so, according to the heat of the bakehouse, the sponge rises a second time, and just as it is about to break again, or when the air escapes by the bursting of the bubbles, about 3 pailfuls of water to make up the batch are poured into the sponge from the seasoning tub, the water having dissolved in it about 4 lbs. of salt and 8 oz. of stuff, (some use 16 oz. of stuff, or even more.) The liquor ought to be well mixed with the sponge; which being done, the pin-board is taken away, and the whole of the flour is worked up into one mass, which is blocked up by the pin-board to one end, and left about an hour in summer, and 2 hours in winter to *prove*. The vacant part of the trough is then sprinkled with flour, to prevent the dough from sticking, the pin-board is knocked out, and the dough is pitched out of the trough on the lid of the opposite trough, when it is cut into masses and weighed, or *scaled off* as it is

Fig. 229. SCALING OFF.

called. These masses are then moulded into shape, and put aside in a regular manner to be finally moulded into loaves, taking care to mould those first which were first scaled off. Previous to moulding, the oven must be well swabbed out, and the up-sets chalked, to prevent the bread sticking to them. They are then placed at the back and on each side of the oven by means of the peel. The long loaves, or the quartern and half-quartern bricks, are put into the oven, packed together as close as possible. The common round bread is also packed close, but the cottage bread must be placed separately, each loaf by itself, or it will not be crusted all round.

After *setting the batch,* that is, placing the loaves in the oven, (Fig. 230,) which requires a good deal of skill, a set-up is placed in front of it. The potatoes for the next ferment are put into a kettle, and placed

Fig. 230. THE OVEN

in the oven to boil. When the potatoes are done, and while still hot, the ferment for the next batch must be mixed. Twenty-four hours elapse from the mixing of the ferment to the time when the bread is taken out of the oven.

In this process we see that the London baker in the manufacture of bread makes use of potatoes, yeast, flour, water, salt, and stuff. A few remarks are necessary respecting each of these ingredients.

As a sack of flour weighs 280 lbs., the addition of so small a quantity of potatoes as 8 lbs. cannot be for the purpose of adulteration. It is true that some of the cheap-bread bakers use a very much larger proportion, with a fraudulent intention, potatoes being cheaper and less nutritious than a similar weight of wheat flour. There is, however, nothing injurious to the health of the consumer in the practice, and the addition of 7 or 8 lbs. of *fruit,* as the bakers term it, to a sack of flour, is said to assist fermentation, and to improve the appearance of the bread.

A far more objectionable material is *alum,* which is used by the bakers under the name of *stuff* or *rocky.* Its object is to bleach the bread, but the manner in which it acts as a bleaching material is by no means understood. It is, however, positively stated that if it be omitted, the bread, instead of being white, is brown. The proportion of alum to a sack of flour is much less than is generally supposed; and it is even less than the bakers themselves are aware of, for as they are liable to a heavy fine if alum be found on the premises, they purchase packets of *stuff* ready prepared for them by the druggists. The bakers suppose this to be ground alum, whereas, it actually consists of 1 part alum and 3 parts of common salt. This mixture is sold in pound packets at 2*d.* each. 8 oz. of this stuff are used to a sack of flour, so that the quantity of alum is only 2 oz. to 280 lbs. of flour, a quantity too small to have any injurious effect on the health. The presence of alum also causes the loaves to break from each other with a much smoother surface than if it were absent.

It is stated that gypsum, chalk, pipe-clay, and blue

and white vitriol have been used to adulterate bread. These are most pernicious adulterants. Ground bones are also mentioned among the adulterants, but the reduction of bones to a powder fine enough for the purpose of adulterating flour would be more costly than the flour itself. We believe, however, that the chief adulterant of bread is in the flour itself, good flour being adulterated with an inferior flour, or with the flour of beans or peas. These, together with potatoes, are perfectly harmless. The great objection to their use is that the customer pays for them the same price as he would do for the fine flour.

Salt is a necessary article of food, and it is added to bread for the purpose of flavour. If the quantity be large, the bread retains more moisture than it otherwise would, and thus weighs heavier. But the taste of such bread sufficiently indicates its bad quality; it is rough in the grain, and two adhering loaves generally separate unevenly. The usual allowance of salt is an ounce to the quartern loaf; but the salt may be introduced by combining its constituents in the dough, for which purpose the flour is mixed up with a solution of carbonate of soda, and then a solution of muriatic acid is added. The carbonic acid thus disengaged will supersede the use of yeast, and will form, when baked, a light and excellent bread.

The usual method of fermenting bread is by means of yeast. This is obtained from the London brewers, or is manufactured for the purpose, as already noticed. Ale-brewers' yeast is well adapted to the purpose, but it cannot be obtained in sufficient quantity. The yeast of the porter-brewer is too bitter and too highly coloured to be used without a previous washing. Distillers' yeast has neither bitterness nor colour, but it is scarce. In warm climates, where yeast cannot be had, other ferments are substituted. In the East Indies bread is raised by means of a liquor called *toddy*, which flows from the cocoa-nut tree when its branches are cut. It ferments so rapidly, that in two or three hours it becomes an intoxicating liquor. In the West Indies *dunder* is used. This is a liquor remaining in the still after the distillation of rum.

The flour ought to be some weeks old before it is made into bread. A sack of flour weighing 280 lbs., and containing 5 bushels, generally produces 80 loaves. According to this, $\frac{1}{5}$th of the loaf is water and salt, and $\frac{4}{5}$ths flour; but the number of the loaves depends on the goodness of the flour. Good flour requires more water than bad, and old flour more than new; 82, 83, or even 86 loaves may in some cases be made out of a sack, and in other cases scarcely 80. There is a considerable loss of weight baking, the average loss in a quartern loaf being $9\frac{1}{2}$ oz., or not quite $\frac{1}{7}$th. If we take the loaves as peck, half-peck and quartern, the following were found within 48 hours after baking to be the weights before and after putting in the oven:—

	Before. lbs.	oz.	dr.		*After.* lbs.	oz.	dr.
Peck	19	12	0	avoirdupoise.	17	6	0
Half-peck .	9	14	0	—	8	11	0
Quartern . .	4	15	0	—	4	5	8

The loaf which presents the greatest surface in the oven loses most weight.

In the time of bad harvests, when the wheat is damaged, the flour may be considerably improved, without any injurious result whatever, by the addition of from 20 to 40 grains of carbonate of magnesia to every pound of flour.

The water used in making bread ought to be of good quality. It is stated that if the flour be kneaded with water saturated with carbonic acid gas, no yeast is necessary, and that bakers who live near Selzer water springs may substitute such water for yeast.

The Bakers of London constitute the nineteenth Company. They were incorporated about the year 1307, and consist of a master, 4 wardens, 30 assistants, and liverymen, and commonalty.

An expeditious and simple method of making bread for a small family is thus described in the Guide to Trade:—Take half a bushel of flour, and put it all except about 4lbs. into a tub or pan, and in winter place it before the fire to warm. Mix 6 or 8 ounces of powdered salt with the flour, or work it in with the dough. Then take a pint of good fresh yeast, and mix it well with a sufficient quantity of water at a blood heat. Make a deep hole in the middle of the flour; pour the water and yeast gradually into it, mixing the whole together with your hands until they are well incorporated. Cover this mixture up, and place it near the fire till it is well risen. Then work the remaining flour into it with your fists till it become a nice, smooth, tough dough. Make this dough into loaves, and bake in an oven properly heated. It will take from $1\frac{1}{2}$ to 2 hours in baking, but the bread should always remain in the oven half an hour after it has become brown, or it will not be *soaked* through.

For larger bakings, put the flour into a trough or tub sufficiently large to allow the dough to swell. Make a deep hole in the centre of the flour. For half a bushel of flour take a pint of thick fresh yeast (not frothy), and mix it with a pint of fresh warm water, not too hot. Then gently mix with the yeast and water as much flour as will make it into a stiff batter. Pour this mixture into the hole in the flour, and cover it by sprinkling it over with flour. Then place over it a flannel or sack, and in cold weather place it near the fire, but not too near. When the sponge has risen enough to crack the dry flour with which it is covered, sprinkle over the top 6 oz. of salt (more or less according to taste). Then work it with the rest of the flour, and add from time to time warm water till the whole is sufficiently moistened, or scarcely so moist as pie-crust. Next work it well by pushing your fists into it, then rolling it out with your hands, folding it up again, kneading it again with your fists, till it is completely mixed and formed into a stiff, tough, smooth dough. Form your dough into a lump like a large dumpling, cover it up and keep it warm. After rising for about 20 or 30 minutes, make it into loaves, having shaken a little flour over the board to prevent sticking. The loaves may be

made up in tin moulds, or you may divide the dough into equal parts according to the size required, and make each part into the form of a dumpling, and lay one of these upon another, then put the loaves into the oven, and bake for $1\frac{1}{2}$ or 2 hours.

In the Pharmaceutical Journal several recipes are given for making unfermented bread. In a paper by Mr. H. Deane, contained in the third volume, the following recipe, by Dr. Smith, of Leeds, is given:—

5 lbs. of flour.

$\frac{1}{2}$ oz. (apothecaries' weight) of sesquicarbonate of soda.

$\frac{1}{2}$ drachm of sesquicarbonate of ammonia.

4 drachms or teaspoonfuls of common salt.

Mix these intimately together, and then add the following solution:

50 oz., or $2\frac{1}{2}$ pints, imperial, of cold water,

5 drachms of hydrochloric acid.

This bread is easily made, requires little labour, no kneading, or time for the dough to rise. It costs a trifle more than bread made with yeast, but has the advantage of keeping longer without turning mouldy or sour, and is wholly free from any bitter or unpleasant taste. Its dietetic properties are of the utmost importance. Common bread is liable in weak stomachs to turn sour, and produce heartburn and flatulency, and to aggravate cases of dyspepsia; but bread made by the new process is free from these baneful effects. Its daily use in health prevents these symptoms, and in many cases it corrects that morbid condition of the stomach and intestines on which these symptoms depend. It is useful in assisting to restore the biliary, and especially the renal, secretions to a healthy condition, as well as in the treatment of various cutaneous eruptions, originating in disorder of the digestive functions.

Mr. Deane's recipe is as follows:—

4 lbs. flour.

$\frac{1}{2}$ oz. (avoirdupois weight) of bicarbonate of soda.

$4\frac{1}{2}$ fluid drachms of hydrochloric acid (specific gravity 1.16).

$\frac{1}{4}$ oz. common salt.

40 fluid ounces, or 2 pints imperial, of cold water.

Mix the soda perfectly with the flour, and the acid with the water, then the whole intimately and speedily together, using a flat piece of wood, or spaddle, for the purpose. It may be made into 2 loaves, and put into a quick oven immediately. It will require about $1\frac{1}{2}$ hour to bake.

In this kind of bread, kneading will prove injurious, by making it too heavy. The dough must not be too stiff.

BREAKWATER. An artificial barrier, designed to *break* the force of the waves in sea-ports and harbours, and thus to protect the shipping from serious damage. Breakwaters are of various kinds, according to the nature of the roadstead or harbour, and the number of ships resorting thereto. In some cases, the roll of the waves is sufficiently checked by sunken vessels placed across the entrance of the harbour; in others, by moles, or piers projecting from the land; but there are cases, such as that of Plymouth Sound, where a large assemblage of ships cannot find a safe place of rendezvous without an erection of far greater magnitude than these. Plymouth Breakwater presents a very remarkable instance of human skill and perseverance, successfully applied. It consists of an immense number of blocks of stone, thrown into the Sound, until a barrier nearly a mile in length was raised above the surface of the water, stretching across the Sound, and leaving entrances at both ends. This great undertaking was commenced in August 1812, and so early as the end of the second year, about eight hundred yards of the breakwater began to appear at low-water, and the swell was so much broken that ships of all sizes began to take shelter within the breakwater, and fishermen within it could not judge of the weather outside the Sound. Some limestone quarries near the Catwater were purchased of the Duke of Bedford for 10,000*l.*, and about fifteen vessels were constantly employed in conveying the masses of stone (varying in weight from one ton to ten tons) to their destined place. Many ingenious devices were employed to hasten the progress of the work, so that, during the first five years, the amount of stone deposited gradually rose from 16,000 to 300,000 tons per annum. The large masses were first lowered, and then smaller stones, quarry rubbish, rubble, and lime screenings, to fill up the cavities and form a compact mass. This structure was completed in March 1841, with the use of 3,369,261 tons of stone, and at the cost to Government of nearly a million and a half of money. The construction of this breakwater was at the time an object of the greatest interest in our own country, and to foreigners visiting us. A celebrated French engineer (Dupin) described in terms of high praise the working of the quarries, the order, regularity, and activity visible in all the operations, the embarking and disembarking of the materials, &c. "Those enormous masses of stone," he says, "which the quarrymen strike with heavy strokes of their hammers; and those aërial roads of flying bridges, which serve for the removal of the superstratum of earth; those lines of cranes, all at work at the same moment; the trucks all in motion; the arrival, the loading, and the departure of the vessels; all this forms one of the most imposing sights that can strike a friend

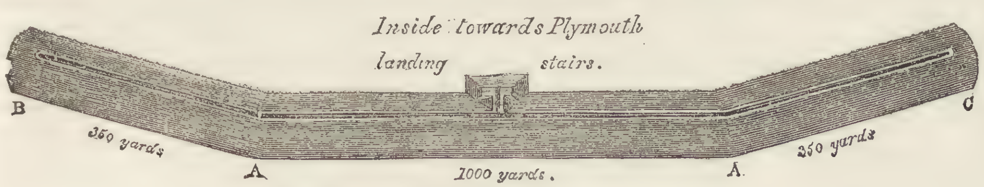
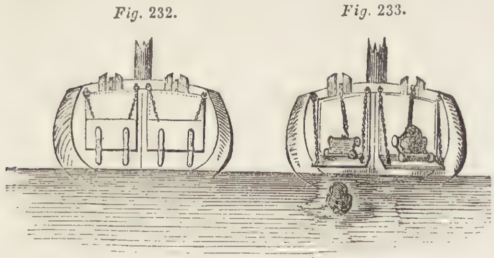


Fig. 231.

to the great works of art. At fixed hours the sound of a bell is heard, in order to announce the blasting of the quarry. The operations instantly cease on all sides; all becomes silence and solitude. This universal silence renders still more imposing the noise of the explosion, the splitting of the rocks, their ponderous fall, and the prolonged sound of the echoes."

The vessels employed for transporting the stone to the site of the breakwater (marked out in the sound by a line of buoys) were of a peculiar construction. They had two railways laid along them, parallel to each other, with openings in the stern, to admit the trucks laden with stones. These were wheeled from the quarry to the quay, thence to the openings in the vessel, and along the rails laid down in it, until both these lines of rail were filled with trucks. The vessel then proceeded on its way, bearing its load of trucks and stones, and, on reaching the breakwater, each truck was wheeled to the opening, where by machinery it was overset, and the stones cast into the sea. Fig. 232 shows the stern of the vessel, when loaded, with the ports up or closed; Fig. 233 shows

Fig. 232. *Fig. 233.*



the stern of the vessel in the act of depositing the stones. The runner being hooked to the forepart of the truck, raises it up, and tips the stone overboard. By these means a cargo of sixty or eighty tons could thus be discharged in an hour.

A breakwater was thus formed, having a centre 3,000 feet long, and two arms, or bends, each 1,050 feet long, inclining towards the land. At the extremity of the western arm a circular foundation was prepared, on which a lighthouse has been placed. The entrance into the harbour on this western side is the principal entrance for shipping: it is about half a mile wide, and at low-water spring-tides the depth of water varies from seven to nine fathoms. The eastern entrance is of about the same width, but the depth of water is not so great, being about six or seven fathoms. The outer slope of the breakwater below the line of low-water was formed by the sea, and proves to be from three to four feet horizontal to one of perpendicular; from the low-water line upwards it is five to one. The inner slope is two feet horizontal to one perpendicular, from the base to the top, which is two feet above high-water spring-tides. When the action of the sea had formed its own slope, and had wedged together and settled the great mass of materials which forms the breakwater, and when no further movement was apparent, but the whole appeared consolidated together, then the slope towards the sea was cased with regular courses of masonry, dowelled, joggled, dove-tailed, and cramped together; the diving-bell being brought into requisition for placing the lower courses, which were of granite, and were laid horizontally on their natural beds, and dove-tailed, lewised, and bolted together.

The Plymouth breakwater is capable of affording secure and convenient anchorage to a fleet of twenty-five or thirty sail of the line; and the additional advantage of a plentiful supply of fresh water is afforded by the construction of a reservoir above Bouvisand Bay, capable of containing from ten to twelve thousand tons, or a quantity sufficient to water fifty sail of the line. This water is brought in pipes to Steddon Point, opposite the anchorage, where a jetty is thrown out, from which the water descends through the pipes to the ships' boats. The whole expense of this valuable arrangement was about 16,000*l*.

In the construction of the Plymouth breakwater, experience had been gained by the failure of a previous attempt made on the French coast at Cherbourg. Under the direction of the French government, M. de Cessart prepared a plan for a barrier in the middle of the sea, and in front of that roadstead; but, unfortunately, he adopted, as the only mode of producing smooth water, the idea of a number of large masses of a conical form, touching each other at their base, but separating upwards, and leaving alternate openings and points of resistance, which, it was thought, would effectually break down and interrupt the waves entering the harbour. It was proposed to construct these conical caissons of wood, the number of which, to cover the destined extent of 2,000 toises, would amount to 90, causing a total expense of 32,400,000 livres for the whole. The number was afterwards reduced to 64, and the estimated time for completing them was thirteen years. Each cone was to be 150 feet diameter at the base, and 60 feet diameter at the top, and from 60 to 70 feet in height; the depth of water at spring tides, in the line in which they were intended to be sunk, varying from about 56 to 70 feet. Within the exterior cone was an interior and concentric one, bound together by beams of wood. The frame of each cone was composed of 80 large upright beams, 24 feet long, and 1 foot square. On these were erected 80 more, of 14 feet in length, making in all 320 large uprights. The machine was then planked, hooped, and firmly fixed together with iron bolts. The cones were to be sunk empty, and without bottoms, and were to be filled afterwards. On the 6th of June, 1784, the first cone was floated off, and sunk, and, on the 7th July following, a second, in the presence of ten thousand spectators; but before the cavity of the latter could be filled with stones, a storm in August, continuing five days, entirely demolished the upper part of the cone. The quantity of stones sunk that summer within the cavities of the two cones, outside their bases, and in the intermediate space, amounted to about 65,000 tons. In 1785, three more cones were sunk, and in the following year, five more, but the storms of

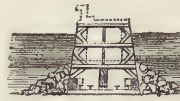
winter carried away the upper parts of those five. Three were sunk in 1788; but these met with the same fate, so that government, in disgust at the delay and expense, sold the three cones then on the building-slips for whatever they would fetch. The array of persons employed on this undertaking was enormous. M. de Cessart, in order to make, and sink, and fill five cones a-year, found it necessary to have 250 carpenters, 30 blacksmiths, 200 stone-hewers, 200 masons, and 520 general labourers. In the whole operation from first to last, there were employed from 1,200 to 1,500 artificers and labourers, and to these were added about three thousand soldiers, for a body of troops had been marched to Cherbourg on the commencement of the undertaking, that there might be no lack of labourers to carry it into effect. This affords a remarkable contrast to the small establishment employed to carry on the Plymouth breakwater. Here there were the following persons:—

	Persons.
A superintendent and proper officers and clerks, to keep and control the accounts	10
Warrant-officers and masters of the ten stone vessels, in the immediate employ of the public	21
Seamen and boys to navigate these vessels	90
Seamen employed in the superintendent's vessel, the light vessel, boats' crews, &c.	45
Masons, blacksmiths, carpenters, sailmakers, employed at Oreston . .	39
In the immediate pay of Government	205
Seamen employed in the contractors' vessels	170
Quarrymen, labourers, &c. employed at Oreston by the contractors . .	300
	675

The engineer of the Plymouth breakwater was Mr. Rennie, who did not live to carry through the whole of his undertaking; the lighthouse on the western extremity having been constructed from his designs by Messrs. Walker and Burgess. Among the plans rejected by Government at the time that his was adopted, was one for a floating breakwater, composed of triangular or prismatic floats of wood, held together by iron chains. These might be extended across the whole sound, because they would allow a great part of the tide to pass through them, while the whole water-way below would be left clear. Sufficient intervals were to be left between the rows of floats, as well as the contiguous floats, to allow of ships shaping their course between them; and it was not thought likely that, in the event of a ship striking against, or even running over, one of these breakwaters, it would occasion any material injury to either. A floating breakwater, on a somewhat similar plan, has since been made the subject of a patent, and its practical application undertaken by a joint-stock company.

A patent was taken out in 1848 by Mr. Beardmore, for an invention designed to facilitate the construction of breakwaters and other submarine works. It consists in the employment of a caisson or enclosure, constructed so as to float, with a portion of the structure built therein, to the spot where the breakwater is to be placed, and to constitute a part of the permanent work, which may be proceeded with to completion, with more expedition and convenience, and less liability to damage, than is usually experienced in such structures. The caisson consists of wrought-iron plate bottom, sides, and ends, and occasional transverse bulk-heads, strengthened by ribs, and firmly connected together, so as to withstand pressure in every direction; the whole being so bonded together as to constitute one entire frame, of great strength, solidity, and power of resisting strains. When sunk, with its enclosed masonry, it would at once form a solid foundation and a material part of the permanent work. A transverse section of one of these caissons, with its sides filled in with stones, is shown at Fig. 234.

Fig. 234.



BREAST-WHEEL. [See HYDRAULICS.]

BREWING. [See BEER.]

BRICK. A building material, known at a very early period of the world's history, formed of tempered clay, hardened either by exposure to the sun's rays, or to the heat of a furnace. Bricks were used in the building of Babel, and it would appear that they were *burnt* bricks. ("Let us make brick, and burn them throughly. And they had brick for stone, and slime had they for mortar." Gen. xi. 3.) Also in the walls of Babylon, where the clay thrown out of the trench surrounding the city, supplied the material; and especially in the pyramids and other buildings of Egypt, where their manufacture gave employment to a vast number of persons, and at last became important enough to be undertaken by the state. Thus the public purchased of the government, and private individuals were forbidden to engage in the manufacture, or to use any bricks to which the government stamp was not affixed. The brick-makers worked in gangs, under the superintendence of overseers and task-masters; the clay was worked up with chopped straw, and the bricks prepared from it were dried in the sun. The employment was laborious, and the task-masters were as exacting as in later times. (Exod. v. 6—19.) The principal pyramids of Egypt are built of stone, but several of the smaller are of brick, as that of Howara, which is constructed of crude bricks, containing chopped straw. These bricks measure $17\frac{1}{2}$ inches by $8\frac{3}{4}$ inches, and are $5\frac{1}{2}$ inches thick. In some cases the bricks contain not only straw, but pieces of broken pottery and stone, and are very irregular in size. A brick pyramid about ten leagues from Cairo, is supposed to be that mentioned by Herodotus, as having once borne the following inscription: "Disparage me not, by comparing me with pyramids made of stone:

I am as much superior to them as Jove is superior to the rest of the deities: I am constructed of bricks, made from mud, which adhered to the ends of poles, and was drawn up from the bottom of the lake."

Unburnt bricks were used in the walls of Athens, and in the construction of several Grecian temples and palaces. Vitruvius expressly describes the manner in which these bricks were made, and the proper seasons for drying them regularly; namely, spring and autumn. The inhabitants of Utica made use of such bricks only as were five years old, and had been approved by a magistrate.

The Romans made use of bricks to a far greater extent than the Greeks, as the remains of their public edifices plainly show: some of their brick structures raised 1,700 years ago still remain as entire as when first built. To that people, doubtless, we are indebted for the introduction of the art into Britain. But the use of brick does not appear to have become general in this country until after the Norman conquest, nor to have attained any remarkable degree of perfection until so late as the reign of Henry VIII., when many interesting buildings were constructed of this material, in a style which has made them objects of admiration in our own age. Yet it was only for the more important edifices that brick was solely used; the ordinary houses consisted of a frame-work of timber, either filled in with lath and plaster, or with bricks introduced in panels. The danger of so great use of timber in a crowded city became evident when the great fire of London desolated the homes of the metropolis, and after that event, it was wisely ordained that brick should be the material of the future city, and that even the ornamental part of the houses should be contrived in the same material. Thus, brick-work came to be carved and made to assume the forms which more properly belong to stone, such as Doric pillars, and rich entablatures curiously wrought with the chisel subsequent to the erection of the walls. In Holland the art of making very durable bricks was practised at an early period, the floors and pavements being constructed of that material. These remain uninjured for a surprising length of time, and exhibit the superior quality of the brick. English bricks are decidedly inferior to these, not on account of any defect in the materials, but on account of the saving of labour and fuel which is sought after in the majority of cases, and which is rendered necessary by the mania for cheapness. The system prevailing in the metropolis fosters this mania, for the great majority of the lands are let on building leases, and it is to the interest of the builder to erect houses which shall merely last out the lease, since, at the expiration of that period they become the property of the landlord.

The operations connected with ordinary brick-making are briefly these: digging the clay in autumn; leaving it to mellow by frost during winter, the masses being frequently turned and broken up, to expose them more completely to the action of the atmosphere: throwing the crumbled clay in spring into shallow pits, where it is watered and soaked: then tempering the clay by treading and kneading by the feet either of men or oxen, or by means of a horsemill: next conveying the kneaded clay to the bench of the moulder, who takes a lump and dashes it into a wooden or iron mould, striking off the superfluous clay with a strike or smooth piece of wood. The bricks are delivered from the mould, and ranged on a barrow or on the ground, until they are firm enough to bear handling, when they are trimmed with a knife. They are then built up in long dwarf walls, with sufficient space for the air to penetrate in every direction: these walls are thatched as a protection from the weather, and thus the bricks are left to dry until they are in a proper state to be consigned to the kiln.

The various argillaceous earths used in brick-making are generally mixed with some other substance, being for the most part unfit to be used alone. Some are almost pure clay or alumina, and are strong, and exceedingly plastic, but cannot be dried without splitting. Others, being light sandy clays or loams, are too loose to be made into bricks without the admixture of lime as a flux, to bind the materials together. Others again are natural compounds of alumina and silica; but these if free from lime, magnesia, or metallic oxides, are exceedingly valuable clays, being from their infusible nature adapted for making fire-bricks for lining furnaces, for making crucibles, glass-house pots, &c. Fire-clay is found throughout the coal-measures, and occurs in abundance, and of excellent quality, at Stourbridge, and also in the vicinity of Newcastle and Glasgow.

Bricks for ordinary uses are known as "place-bricks," "grey and red stocks," "marl-facing bricks," and "cutting bricks." The place-bricks and stocks are the ordinary wall bricks. The marls are very superior bricks, made in the neighbourhood of London, and used on the outside of buildings. The finest kind of marls and red bricks are called cutting bricks, and are used in arches over doors and windows, being rubbed to a centre and gauged to a height. The red bricks made of Hedgerly loam, from a village of that name, near Windsor, are used as fire-bricks about furnaces and ovens. Foreign bricks are *Dutch* and *Flemish* bricks and clinkers: they are similar in quality, and of a dirty brimstone colour. The first two are used for paving yards, stables, &c., and the clinkers which are most baked are used for ovens. Place-bricks are also used in paving dry, or laid in mortar, and they are put down flat or edgewise. If they are laid flat, 32 of them will pave a square yard; if edgewise, twice that number are required. Ventilating bricks are an invention of modern times. They are double the size of common bricks, although they contain only the same quantity of clay. They are hollowed out at the sides, so that when two are placed side by side, a circular opening is left between them, which, when tiers of similar bricks are laid on, forms of course a

tube within the wall, and this may be applied to the purpose of either warming or ventilation.

The first process in brick-making is the tempering of the clay, which, as we have said, is the work of early spring, after it has lain exposed to the frost during winter. Great care is then taken as the clay is being turned over and tempered with water, to remove by hand every stone that can be discovered in the plastic mass; for the presence of even a small pebble in a brick causes it to crack in drying. Of course this hand-picking is impossible where much gravel occurs: in such cases the clay must be washed in a trough filled with water, until it becomes liquid enough to pass off through a grating into pits prepared for its reception; the gravel meanwhile being retained by the grating. In districts where veins of skerry or impure limestone abound, it is found desirable to grind the clay between rollers, which crush the limestone, and thus obviate the evil which arises when even a small piece of this substance remains in a brick, and by the carbonic acid driven off from it in burning, forces a hole in the brick, and destroys its usefulness.

For the marl, or *malm* bricks, made near London, and used for the best outside work in houses, the clay is dug in autumn, ground to a pulp at once in a wash-mill, and mixed with chalk previously ground to the consistence of cream. This pulp is run off through gratings, and allowed to settle until it is firm enough for a man to walk upon it: it is then covered with finely-sifted ashes, and allowed to remain all the winter to mellow. In the spring the ashes are thoroughly mixed with the clay and pugged in a pug-mill. This is a conical wooden tub, having the larger end upwards, with an upright revolving shaft passing through it, armed with a number of knives, which cut and knead the clay, and force it through the mill, which is constantly filled at the top from the barrows of the work-people, while the clay

Fig. 235. PUG-MILL.

continually issues from a hole in the bottom, where it is cut into convenient pieces and piled up for future use. The pug-mill is extensively used where the demand for bricks is large, and where the brick-earth is favourable in quality; but in many country places the indispensable labour of kneading the clay is still performed by the treading of men's naked feet, which become by constant practice sensitive to the slightest roughness in the mass, and able to detect the smallest stone or impurity.

When the clay has been reduced by one of these processes to the necessary state for brick-making, masses of it are successively brought to the moulder's bench. The mould is without top or bottom, and the workman's art consists in dashing a piece of clay with such force into it, as completely to fill it, and then cleverly striking off the superfluous quantity, and turning out the brick on a pallet, which is placed by a boy on a hack-barrow, which when loaded is wheeled away to the hack-ground, where the bricks are built into long low walls to dry. By another plan, the bricks are shifted at once from the moulder's bench to a drying floor, from thence to the hovel, or drying shed, and from the hovel to the kiln.

The moulder's bench is a rude kind of table, often provided with a trough for water, as well as a heap

Fig. 236. MOULDER'S BENCH.

of sand, the mould being either dipped in water, or sanded, between the making of each brick, that the clay may not adhere. If water is used, the process is commonly called *slop-moulding*, if sand, *pallet-moulding*. In the neighbourhood of London, women commonly take part in the operations. Fig. 236 represents a woman thus engaged. The moulds were formerly of wood only; they are now sometimes made of brass, cast in four pieces, and riveted together, or of wood lined with brass, sometimes of wood with the edges of iron, sometimes with the two longest sides of iron. Brass moulds do not require wetting or sanding; but they are expensive, and the edges soon become worn. Wooden moulds therefore continue in some districts to be largely used. A good form of mould is a wooden mould lined with brass; the wood as well as the brass being in four pieces, and attached by rivets at the angles. This mould costs about twenty-five shillings, and was formerly still more expensive. The brass overlaps the wood at the edges, where it wears out rapidly, and the cost of repair is nearly as much as the original price of the mould. Fig. 237 represents a

mould made of sheet-iron in four pieces, riveted at the angles, and strengthened with wood at the sides. The bottom is separate, and is called a *stock-board.* This is fastened by pins at the corners to the moulder's bench. It is very common at the present time to make bricks with a hollow underneath, both for the sake of lightness, and to leave a bed for the mortar. This is managed by fastening a piece of wood called a *kick* to the upper side of the stock-board. The mould being placed on the stock-board, (which easily and accurately fits it,) and the clay pressed into the mould, a hollow space corresponding to this kick is of course formed on the under side of the brick. The pallets are pieces of board $\frac{3}{8}$ths of an inch thick, of the same width as the mould, but a little longer. Six-and-twenty pallets form a set, and three sets are required for each moulder. Fig. 238

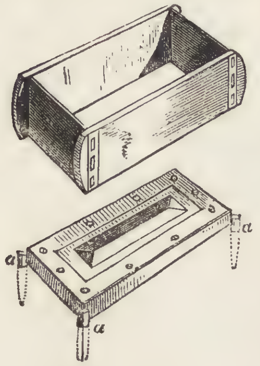


Fig. 237.

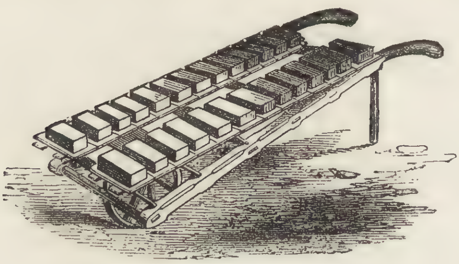


Fig. 238. HACK-BARROW.

represents the bricks on one set of pallets, ranged on the *hack-barrow,* which has a flat top of light framework, fit to receive two rows of bricks, thirteen in each row. Three of these barrows are required for use at each moulder's bench, one being constantly loading there, another unloading in the drying ground, and the third being wheeled to and fro. The low walls of bricks in the drying ground are called *hacks.* These are built two bricks wide, and eight bricks high, and the bricks are generally placed slanting, and not at right angles to the length of the wall. When the bottom row of one hack is formed, the workman begins a second hack, leaving the first to get firm before it has to bear the weight of a second row. Plenty of straw or hay is at hand to cover up the bricks at night, or in bad weather. For the finer descriptions of bricks, drying under cover is adopted, and in some instances flues are carried under the floors of the drying sheds, and currents of air are carefully excluded.

Where the demand for bricks is very large, brick-moulding is performed by machinery. A number of machines have been invented for this purpose, and some of them have answered the end very well. But it is doubtful whether the pressure employed is really an advantage. The density of the bricks is thereby increased, and they are smoother, heavier, and stronger than other bricks, which for some purposes is desirable, but they do not adhere so well to the mortar, they are difficult to dry well, and their weight adds to the expense of carriage, and prevents the workman from laying so many in a given time, as of the hand-made bricks. Machine-made bricks are also frequently disfigured by a ridge caused by the clay rising a little way up the sides of the piston, in the space which, without careful workmanship, is apt to occur between the piston and the mould.

Two brickmaking machines much in favour in this country are Ainslie's and Hunt's. The latter has been extensively used in the execution of large contracts, and consists of two cylinders, each covered with an endless web, which are so placed that they form a sort of hopper on their two upper cylindrical surfaces, the ends being enclosed by two iron plates. The tempered clay is thrown into this hopper, and at the lower part it acquires the form and dimensions of a brick. Beneath is worked an endless chain, by the movement of the cylinders, and at various marked intervals are laid the pallet-boards under the hopper; the clay is brought down by a slight pressure, and enters a frame, which has a wire stretched across it, which projects through the mass, and cuts off the requisite thickness; this is immediately removed by the forward motion of the endless chain; and this operation is renewed as often as a new pallet-board is advanced under the hopper. Such a machine produces about 1,200 bricks per hour, and is worked by two men and three boys. By this plan less pressure is given than in most machines, consequently the bricks are less difficult to dry equally. Machine-work is cheaper than hand-labour in the moulding of bricks.

Machinery has been recently employed for making bricks and other articles of clay nearly in the state of a dry powder. The clay is subjected to heavy pressure in strong metal moulds, and is by this means reduced to one-third its original thickness. It retains just sufficient moisture to give it cohesion, and the bricks thus formed can be handled at once, and taken direct to the kiln. This method was devised by Mr. Prosser of Birmingham, and is highly useful for making ornamental bricks, floor-tiles, &c. By an experiment made on a nine-inch brick of this sort, it was found that the resistance to a crushing force is immense, ninety tons having been sustained without injury.

The final process in brick-making is that of burning the bricks in a kiln or in clamps, the former being the old and the best plan. The kiln may be a simple rectangular chamber, built of old bricks and rubble stone, with a narrow doorway at each end, and narrow fire-holes lined with fire-bricks in the side walls exactly opposite each other. The workmen introduce through the doorways a quantity of bricks, and stack them loosely but with considerable art in cross courses, within the walls, leaving openings that shall act as flues throughout the whole

mass, and thus distribute the heat from top to bottom. When the kiln is filled, the top is covered in, and fires are lighted in the fire-holes. The fire is at first got up gently, that the moisture in the bricks may be gradually evaporated; but in two or three days, when the steam ceases to rise, the heat is raised, the doorways are bricked up, and the temperature continued till the fire begins to appear at the top. It is then slackened, and the kiln allowed to cool. The heating and cooling are then repeated, and in about 48 hours the bricks are thoroughly burnt. An ordinary kiln will hold 20,000 bricks. The fuel consists in some places of fagots of furze, heath, brake, &c., in others of pit coals. When bricks are burnt in a clamp, they afford to a great extent their own fuel, for a clamp is an immense pile of carefully arranged bricks, in which *breeze*, (the technical name for ashes,) has been mixed with the clay in their manufacture. But layers of breeze are also added, and the whole is set fire to by means of fireplaces and flues filled with wood, coal, and breeze. The burning of a clamp continues from two to six weeks. The art of clamping well exhibits no mean degree of skill in the workman. They first build an *upright* or double battering wall along the centre, and then arrange a number of other walls in an inclined position on each side, corresponding in length and height with the central wall, and supported by it. The sides and top of the clamp are cased with burnt brick, and the lower courses of the central double wall are of the same material. There are numerous live-holes left in a large clamp, and these are fired in succession. The bricks near these live-holes are burnt too much, and generally spoiled by running together in masses called burrs, and the bricks at the outside of the clamp are not burnt enough, and are laid aside for re-burning in the next clamp. Much judgment is required in apportioning the fuel to the size of the clamp, for the whole may be easily underburned or overburned, and so deteriorated or rendered comparatively useless. The burrs and clinkers, or shapeless masses of fused brick, may often be recognised in the rock-work of suburban gardens, while the pale underbaked bricks, sold at low price, are used in the inferior unsubstantial erections which disgrace the neighbourhood of the metropolis.

The processes above described are not universally prevalent. On the contrary, various differences exist in particular districts. These are well indicated in the following paragraph from Dobson's clever Treatise on "Brick and Tile-making."[1] "In some districts the clay is ground between rollers, and the pug-mill is never used. In others both rollers and pug-mills are employed. In the neighbourhood of London rollers are unknown, and the clay is passed through a wash-mill. Equal differences exist in the processes of moulding and drying. Lastly, the form of the kiln varies greatly. In many places the common Dutch kiln is the one employed. In Essex and Suffolk the kilns have arched furnaces beneath their floors. In Staffordshire, bricks are fired in circular domed ovens called cupolas."

At the close of the last century, bricks were for the first time subjected to taxation. A duty of 2*s.* 6*d.* per thousand was imposed on all bricks, and this was afterwards raised to 4*s.* per thousand. Subsequently, bricks were divided into common and dressed, and separate duties were laid upon each. In 1833, the duties on tiles were wholly repealed, but those on bricks still remained, and were raised two years later, so that common bricks paid 5*s.* 10*d.* per thousand, and superior ones a higher rate. In 1839, the duty of 5*s.* 10*d.* was made general on all bricks, without distinction of shape or quality, and this was felt as a boon, because the restrictions had previously limited the manufacture of various patterns. It was also enacted that bricks used in draining marshy land should be exempt from duty, provided the word "Drain" was legibly stamped upon them. Bricks made in Ireland, and also bricks for exportation, were never subjected to duty, but with respect to the latter, sufficient security was required before shipment that they should not be re-landed in England, and if it was discovered that this was done, the owner had to suffer, over and above the penalty in his bond, the forfeiture of the whole cargo. By a recent act, the duty on bricks was wholly repealed. Notwithstanding the influence of the duty, the number of bricks made in England has nearly doubled during the twenty years ending with 1840, the number that paid duty in 1821 having been 899,178,510, whereas in 1840, it amounted to 1,677,811,134; and the latest accounts make it nearly 1,800,000,000, which produced an annual revenue approaching 600,000*l.* The manufacture of bricks in Scotland is much less important than in England, owing to the extensive use of stone as a building material in that country.

BRICKLAYING is the art of building with bricks, or of uniting them by cement or mortar into various forms. Bricks of English make are commonly of one form, 9 inches long, 4½ broad, and 2½ deep. They vary greatly in quality, according to the quality of the material, the manner in which the clay is tempered, and the method of burning.

The bricklayer, who is always assisted by a labourer, to supply him with bricks, mortar, &c., executes his work by the aid of a few simple tools. These are:—1. A *brick-trowel*, made of well-tempered steel, Fig. 239, for taking up and spreading the mortar, and also for cutting bricks by percussion to any required size; 2. A *hammer*, Fig. 240, for cutting holes and chases in

Fig. 239.

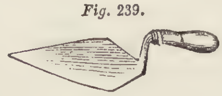


Fig. 240.

Fig. 241.

(1) Weale's Rudimentary Series.

brick-work, and for driving or dividing bricks: to adapt it to these different uses, one end is formed like a common hammer, and the other is furnished with a kind of axe; 3. The *plumb-rule*, Fig. 241, which is a thin rule, six or seven inches wide, with a line and plummet swinging in the middle: its use is to guide the bricklayer in carrying up his walls perpendicularly; 4. The *level*, Fig. 242, which is ten or

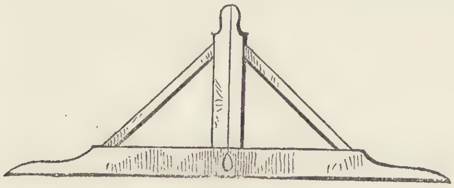


Fig. 242.

twelve feet long, with a vertical rule attached to it, in which a line and plummet are suspended: its use is to try the level of the walls at various stages of the building, as it proceeds, and particularly at the window-sills and wall-plates; 5. The *large square*, for setting out the sides of a building at right angles; 6. The *rod*, for measuring lengths, usually five or ten feet long; 7. The *jointing rule*, about eight or ten feet long, and four inches broad, with which the bricklayers *run*, or mark, the centre of each joint of the brickwork; 8. The *jointer*, Fig. 243, an iron tool, shaped like the letter S: it is used with the jointing-rule for marking the joints; 9. The

Fig. 243.

Fig. 244.

Fig. 245.

compasses, for traversing arches and vaults; 10. The *raker*, Fig. 244, a piece of iron, having two knees, or angles, the points of which are used for raking out decayed mortar from the joints of old walls, for the purpose of replacing it with new mortar, or, as it is called, *pointing* them; 11. The *hod*, a wooden trough, shut close across at one end, and open at the other: the sides consist of two boards at right angles to each other, with a long handle projecting downwards from the middle of the angular ridge formed by the meeting of the two sides; this ridge is also partly covered by a cushion of leather, stuffed with wool, to prevent it from cutting the shoulder of the labourer. The hod is used by the labourer for conveying bricks and mortar to the bricklayer. To prevent the mortar from sticking, dry sand is strewed on the inside; 12. The *line-pins*, Fig. 245, which are of iron, for fastening and stretching the line at proper intervals of the wall, that each course may be kept straight in the face and level on the bed: the pins have a line attached to them, of sixty feet to each pin; 13. The *rammer*, similar to that of paviours: it is used for trying the ground, as well as for beating it solid, before building; 14. The *iron crow* and *pickaxe*, for breaking and cutting through walls, or moving heavy weights.

A *grinding-stone* is also used for sharpening axes, hammers, and other tools.

In the preparation and cutting of gauged arches, the following articles are used: 15. The *banker*, Fig. 246, a bench from 6 to 12 feet long, from $2\frac{1}{2}$ to 3

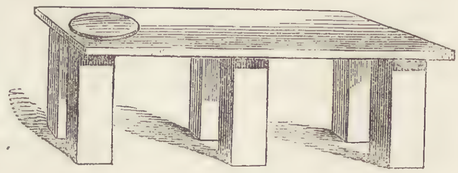


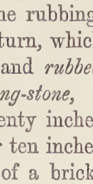
Fig. 246.

feet wide, and about $2\frac{3}{4}$ feet high: its use is for preparing the bricks for rubbed arches, and for other gauged work; 16. The *camber slip*, Fig. 247, a piece

Fig. 247.

of wood about half an inch thick, with at least one curved edge, rising about one inch in six feet, for drawing the soffit line of straight arches. When the lower edge is curved, it rises about half that of the other, or about half an inch in six feet, for the purpose of drawing the upper line of the arch, so as to prevent it becoming hollow by the settling of the arch. The upper edge is not always cambered, some preferring it straight. The slip being sufficiently long, it answers the width of many openings; and when the bricklayer has drawn his arch, he delivers it to the carpenter, to prepare the centre for it; 17. The *rubbing-stone* is a rough-grained stone, about twenty inches diameter, or less. It is fixed upon one end of the banker, Fig. 246, upon a bed of mortar. After the bricks for the gauged work have been rough-shaped by the axe, they are rubbed smooth on the rubbing-stone. The headers and stretchers, in return, which are not axed, are called *rubbed returns*, and *rubbed headers* and *stretchers;* 18. The *bedding-stone*, a straight piece of marble, eighteen or twenty inches long, of any thickness, and about eight or ten inches wide. Its use is to try the rubbed side of a brick, which must be first squared, to prove whether its surface be straight, so as to fit it upon the leading *skew back* or leading end of the arch; 19. The *square*, for trying the bedding of the bricks, and squaring the soffits across the breadth of the bricks; 20. The *bevel*, Fig. 248, for drawing the soffit line on the face of the bricks; 21. The *mould*, for forming the face and back of the brick, in order to reduce it in thickness to its proper taper, one edge of the mould being brought close to the bed of the brick when squared. The mould has a notch for every course of the arch; 22. The *scribe*, a spike or large nail, ground to a sharp point, to mark the bricks on the face and back by the tapering edges of the mould, for the purpose of cutting them; 23. The *tin saw* used for cutting the soffit lines about

Fig. 248.



one-eighth of an inch deep, first by the edge of the level, on the face of the brick, then, by the edge of the square, on the bed of the brick, in order to enter the brick-axe, and to keep the brick from spalting. The saw is also used for cutting the soffit through its breadth, in the direction of the tapering lines drawn upon the face and back edge of the brick, and also for cutting the false joints of headers and stretchers; 24. The *brick-axe*, Fig. 249, for axing off the soffits of bricks to the saw cuttings, and the sides to the lines drawn by the scribes. The bricks being always rubbed smooth after axing, the more truly they are axed, the less labour will be required in rubbing them; 25. The *templet*, used for taking the length of the stretcher and width of the header; 26. The *chopping-block*, for reducing bricks to their intended size and form, by axing them. It is a piece of rough wood, six or eight inches square, supported on two fourteen-inch brick piers; but it varies in size according to the number of men working at it; 27. The *float-stone*, used for rubbing curved work smooth, such as the cylindrical backs and spherical heads of niches, to take out the axe marks. It is previously brought into a form the reverse of the surface to which it is applied.

Fig. 249.

In the raising of brick walls, it is of great importance to secure a good foundation. Trenches are dug for foundations, and the ground is tried with a crowbar or rammer, to ascertain its soundness. If it appear to shake, it must be bored with a well-sinker's tool, to ascertain whether the shaking be local or general. If the soil be firm, the looser parts, if not very deep, are dug up, until the solid bed is got at. If the ground be not very loose, it may be made good by ramming into it large stones, closely packed together; but if the ground be very bad, it must be piled and planked, and in such cases, concrete is of very great service. In rising ground, the foundation must be made to rise in a series of steps. When the ground is loose in places over which it is intended to make windows, doors, &c., while the ground at the sides on which the piers are to stand is firm, it is usual to turn inverted arches over such intended openings, Fig. 250. This is a necessary precaution

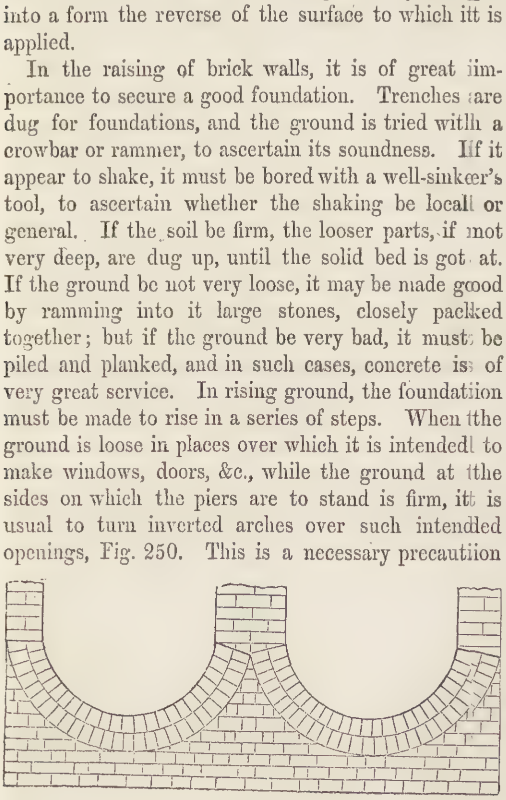


Fig. 250.

in all cases where the depth of the wall below will admit of it; for the piers in settling will carry the arch with them, and, by compressing the ground, assist in securing the structure. These arches should be turned with great exactness, and their height should be at least half their width. The bed of the piers ought to be as uniform as possible, for, although the bottom of the trench may be very firm, yet, if it vary in firmness, the piers will settle more in one place than in another, and thus occasion a vertical fracture in the superstructure. Should the solid parts of the trench be under the intended openings, and the softer parts where piers are to be built, on firm ground, arches, not inverted, must be suspended between them; in which case, attention must be paid to the insisting pier, whether it will cover the arch or not; for if the middle of the pier rest over the middle of the summit of the arch, the narrower the pier, the greater should be the curvature of the arch at its apex. When suspended arches are used, the intrados ought to be clear, that the arch may have its full effect. Here, also, the ground on which the piers are erected must be of equal firmness, lest the building be injured by unequal settling, which is much more mischievous than where the ground, from being uniformly soft, allows the piers to descend equally, in which case the building is seldom or never damaged.

In ramming foundations, the stones, previously chopped or hammered, should be laid of a breadth proportionate to the weight intended to rest on them, and rammed closely together with a heavy rammer. The lower bed of stones may in general project about a foot on each side of the wall: on this another course may be laid, so as to bring the upper bed of stone upon a general level with that of the trench, projecting about eight inches on either side of the wall, or receding four inches on each side within the lower course. The joints of every upper course must fall as nearly as possible on the middle of the stones in the course immediately beneath it; a rule to be strictly attended to in every kind of walling; for in all the modes of laying stones or bricks, the object is to obtain the greatest lap one upon the other.

In slacking the lime for preparing the mortar for the wall, no more water should be used than is barely sufficient to reduce it to powder, and it should be covered with a layer of sand to exclude the air. It is best to slack the lime in small quantities, about a bushel at a time. When the mortar is about to be used, it should be beaten three or four times, and turned over with the beater, so as to incorporate the lime and sand, a little water being added. In hot and dry weather the mortar may be made much softer than in winter. In dry weather, and for fine work, the bricks should be wetted or dipped in water as they are laid; a precaution not required in damp weather. This wetting causes the bricks to adhere to the mortar, which they will not do if laid dry and covered with sand or dust, in which case they may often be removed without any mortar adhering to them. In working up the wall, not more than four or five feet of any part should be built at a time; for, as all walls shrink directly after building, the part which is first raised will settle before the adjacent part is brought up to it, and the shrinking of the latter will cause the two parts to separate. Unless it be for the accommodation of the carpenter, no part

of a wall ought to be carried higher than one scaffold without having the contingent parts added to it. In carrying up any particular part, the ends should be regularly sloped off, so as to receive the bond of the adjoining parts on the right and left.

The strength of brickwork depends on the manner in which the bricks are laid. The practice in England is confined to what is called *Old English bond* and *Flemish bond.* In English bond, Fig. 251, a

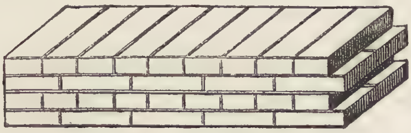


Fig. 251.

row of bricks, laid lengthwise on the length of the wall, is crossed by a row with its breadth in this length, and so on alternately. The courses in which the lengths of the bricks are disposed through the length of the wall, are called *stretching courses,* and the bricks *stretchers.* The courses in which the lengths of the bricks run in the thickness of the walls, are called *heading courses,* and the bricks *headers.* Flemish bond, Fig. 252, which was in-

Fig. 252.

troduced into England about the reign of William and Mary, consists in placing a header and a stretcher alternately in the same course. The effect is more pleasing than the former, but this mode does not produce so strong a wall. The face of an upright wall in English bond is shown in Fig. 253, and that of Flemish bond in Fig. 254.

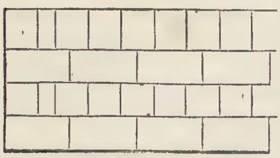


Fig. 253.

Fig. 254.

Fig. 255 is English bond in a nine-inch walling. Mr. Nicholson remarks that, as the length of a brick is nine inches, and its breadth $4\frac{1}{2}$, it is usual, to prevent two vertical joints from running over each other, at the end of the first stretcher from the corner, to place the return corner stretcher, which becomes a header in the face that the stretcher is in below, and occupies half its length; a quarter brick is placed on inside, so that the two together extend $6\frac{3}{4}$ inches, leaving a lap of $2\frac{1}{4}$ inches for the next header, which lies with its middle upon the middle of the header below, and forms a continuation of the bond. The three-quarter bat thus introduced is called a *closer.* A similar effect might be obtained by introducing a three-quarter bat at the corner of the stretching course, and then the corner header being laid over it, a lap of $2\frac{1}{4}$ inches will be left at the end of the stretchers below for the next header, which being laid, the joint below the stretchers will coincide with its middle, and thus form the bond.

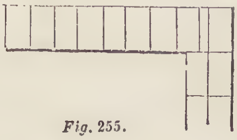


Fig. 255.

In a fourteen-inch, or brick-and-a-half wall, Fig. 256, the stretching-course upon one side is laid so that the middle of the breadth of the bricks upon the opposite side falls alternately upon the middle of the stretchers and upon the joints between the stretchers.

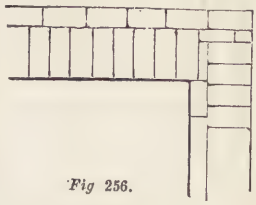


Fig 256.

In a two-brick wall, Fig. 257, every alternate header in the heading-course is only half a brick thick on both sides, which breaks the joints in the core of the wall.

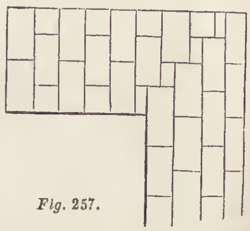


Fig. 257.

In a two-and-a-half brick wall, Fig. 258, the bricks are laid as shown in Fig. 259.

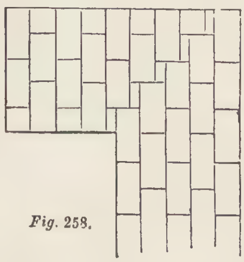


Fig. 258.

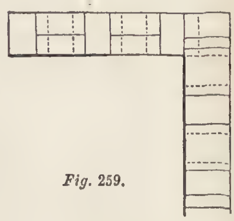


Fig. 259.

Flemish bond for a nine-inch wall is shown in Fig. 260, where two stretchers lie between two headers; the length of the headers and the breadth of the stretchers extending the whole thickness of the wall.

In brick-and-a-half Flemish bond, one side is laid as in Fig. 260, and the opposite side with a half-header opposite to the middle of the stretcher, and the middle of the stretcher opposite the middle of the end of the header.

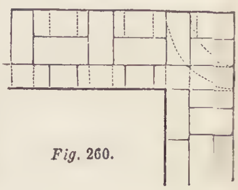


Fig. 260.

The adoption of Flemish bond leads to the frequent splitting of walls; and to prevent it, laths, or slips of hoop-iron, are sometimes laid in the horizontal joints between the two courses. Others have laid diagonal courses of bricks at certain heights from each other. Attempts have also been made to unite complete bond with Flemish facings, for the sake of the improved appearance which the latter gives. In Figs. 261, 262, 263, 264, the interior bricks are represented as disposed so as to unite the two methods,

the Flemish facings being on one side of the wall only; but this arrangement is difficult to execute, as

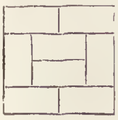


Fig. 261.


Fig. 262.

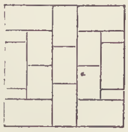


Fig. 263.

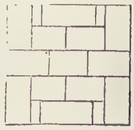


Fig. 264.

the adjustment of the bricks in one course must depend upon the course beneath, which must be recollected by the bricklayer after he has covered the course with mortar. Even should he keep his attention thus alive, the work is not so strong as English bond, which, if executed with the same attention and neatness as is required by the Flemish, would be equally handsome in appearance.

Mr. Nicholson gives the following rules for forming English bond:—1. Each course is to be formed of headers and stretchers alternately; 2. Every brick in the same course must be laid in the same direction; but in no instance is a brick to be placed with its whole length alongside of another; but to be so situated that the end of one may reach to the middle of the others which lie contiguous to it, excepting the outside of the stretching-course, where three-quarter bricks necessarily occur at the ends, to prevent a continued upright joint in the face-work; 3. A wall which crosses at a right angle with another will have all the bricks of the same level course in the same parallel direction, which completely bonds the angles, as shown by some of the preceding Figures.

In building a wall, bricks should incline slightly towards the middle of the wall, that one-half of the wall may act as a shore to the other. It was formerly the practice to build pieces of timber, called *bond timbers,* into the wall, running through its whole length, in order to add to its strength. This method of building walls is objectionable, because if the timber should decay, the wall may fail before any one is aware of the cause of failure. This method of bonding is now almost entirely superseded by the *hoop-iron* bond, which consists in laying hoop-iron flatwise between the courses. The iron should be slightly rusted, by which its adhesion to the mortar is greatly increased.

In winter it is important to preserve the unfinished wall as much as possible from the alternate effects of rain and frost, the one penetrating into the materials, and the other converting the water into ice, which by its expansion bursts, and crumbles the materials. The unfinished wall must therefore be covered with straw, or with a weather boarding in the form of a stone coping, with a body of straw under the wood.

Brick-work is measured by the *rod.* A rod of brick-work taken from the original standard of $16\frac{1}{2}$ feet square, contained in the superficial rod $272\frac{1}{4}$ square feet, but as the quarter was found troublesome in calculation, 272 superficial feet came to be the standard for brick-work. The standard thickness of a brick wall is one and a half brick in length, so that if 272 square feet be multiplied by $13\frac{1}{2}$ inches, the result is 306 cubic feet in the rod. A rod of standard brick-work with mortar, will require 4,500 bricks on an average, allowing for waste, this number depending on the closeness of the joints, and the size of the bricks. The mortar in a rod of brick-work will require $1\frac{1}{2}$ cwt. of chalk lime, or 1 cwt. of stone lime, and $2\frac{1}{2}$ loads of sand with stone lime or 2 loads with chalk lime. The weight of a rod of brick containing 4,500 stock bricks, 27 bushels of chalk lime, and 3 single loads of drift sand, is about 13 tons.

The bricklayer's labourer is paid at the rate of two-thirds of the bricklayer's wages per day. One labourer is sufficient for a bricklayer when on the ground, but as the work advances in height, more may be required. In common walling, where there are few or no interruptions by apertures or recesses, the bricklayer will lay 1,000 bricks in one day, or complete a rod in about $4\frac{1}{2}$ days.

There is a method of constructing a wall with a row of posts or quarters 3 feet apart, the intervals of which are filled up with brick-work. This is called *bricknogging.* It is seldom more than the width of a brick in thickness, and should not be used where thickness can be obtained for a nine-inch wall.

After a wall is built, the joints of the bricks on the face are sometimes filled up with mortar, so as to present a regular and neat appearance. This is called *pointing,* and is of two kinds, in both of which the mortar in the joints is well raked out, and filled up again with blue mortar; but in one kind, called *flat-joint pointing,* the courses are simply marked with the edge of a trowel. If in addition to this, plaster be inserted in the joints with a regular projection, and neatly pared to a parallel breadth, this is called *tuck-pointing* or *tuck-joint pointing.*

Groined arches are sometimes made of brick. A groin is the angular curve formed by the intersection of two semi-cylinders or arches. They are raised on centres formed of carpentry work. The turning of a simple arch on a centre requires only care to keep the courses as close as possible, and to avoid the use of much mortar on the inner part of the joints. The difficulty of executing a brick groin arises from the peculiar mode of making proper bond at the intersection of the two circles as they gradually rise to the crown, where they form an exact point. In the meeting or intersecting of these angles, the inner rib should be perfectly straight and perpendicular to a diagonal line drawn on the plan. After the centres are set, the application of the brick to the angle will show in what direction it is to be cut. The sides are turned as in common cylindric vaults.

A variety of ornamental brick cornices may be formed by cutting and changing the position of the bricks employed. Others may be formed by chamfering only.

Niches in brick-work form the most difficult part of the bricklayer's art. The difficulty arises from the thinness to which the brick must be reduced at the inner circle, as they cannot extend beyond the thickness of one brick at the crown or top, it being

usual as well as neatest to make all the courses standing.

The chief authority in this article has been Nicholson's New Practical Builder, London, 1823. One of the earliest treatises on Bricklaying is contained in the "Mechanick's Exercises on the doctrine of Handyworks," by Joseph Moxon, third Edition, London, 1703. The Author in his Preface seems to think an apology necessary for writing on such humble subjects as "Bricklayery;" but he says:—"I see no more reason why the sordidness of some workmen should be the cause of contempt upon manual operations, than that the excellent invention of a mill should be despised because a blind horse draws in it."

BRIDGE. An elevated construction upon or over a depression, and between depressed points, probably derived from the word *ridge*, with the prefix *be*. Professor Hosking defines a bridge as "a constructed platform, supported at intervals or at remote points, for the purpose of a road-way over a strait, an inlet or arm of the sea, a river, or other stream of water, a canal, a valley, or other depression, and over another road; distinguished from a causeway, or embanked or other continuously-supported road-way, and from a raft, by being so borne at intervals or at remote points."[1] Aqueducts, for conveying streams of water or canals, and viaducts, for carrying roads or railways, upon the same, or nearly the same, level, over depressions, are practically considered as bridges.

One of the most important requisites in a bridge is permanence. It ought to form a portion of the solid road which it connects, so as to combine comparative ease of approach with convenience of passage and agreeableness of design. The whole depression or valley must practically be obliterated in its effect upon the road, by means of the bridge passing from one summit to the other, so that the ordinary traffic may be carried on without interruption. The bridge must also afford facility of passage under it, not only for the stream, but also for the commerce of men and merchandise which are borne along upon the waters.

But a bridge is not limited to one particular form, size, proportion, material, mode of construction, arrangement, or design, but is such as circumstances require it to be. Where a stream or body of water occurs in the line of a great public road, so as to interrupt its continuity, some kind of bridge is necessary. In a river, estuary, strait, or arm of the sea, where the banks are wide and low, and where the navigation for vessels with lofty rigging is to be kept free, an ordinary bridge may be impossible, and a floating bridge, such as a passage-raft, or punt, may be all that can be allowed. For example, the great mail-road from the metropolis, through Bristol, into South Wales, is intercepted by the Severn: the river is wide; its banks are low; the water is sufficient for marine navigation, and the trade of the country requires that its course should remain open for that purpose. Hence, the erection of a bridge is prohibited. But where the banks are high, and the channel comparatively narrow, a bridge may be thrown over, as in the case of the Wear, at Bishop's Wearmouth, by Sunderland. So, also, the Straits of the Menai are passed over by the great Holyhead road, without impeding the passage of ships through the straits.

(1) "The Theory, Practice, and Architecture of Bridges of Stone, Iron, Timber, and Wire; with Examples on the principle of Suspension: Illustrated by 138 Engravings, and 92 Wood-cuts." Weale: London. 1843.

In treating of so extensive and complicated a subject as that of bridges, the literature of which forms a library in itself, it will be desirable to divide it into sections, by bringing together, *first*, a few notes on the History of Bridges, chiefly of stone; *secondly*, some details respecting the Theory of Bridges; *thirdly*, the Practice of Bridge-building; *fourthly*, Timber-bridges; *fifthly*, Suspension-bridges; and *lastly*, Iron, Girder, and Tubular-bridges.

Section I.—Historical Notice of Bridges.

The art of bridge-building, like all other useful arts, was of slow growth, and has shared in all the varied changes of man's social position at different periods of his history. In a rude state of society, the most obvious and simple bridge is a tree thrown across a stream; or, if the breadth of the stream be too great to be spanned by a single tree, a tree on each side of the stream bent down, and the branches twisted together in the middle. Mungo Park observed this method on the rivers in the interior of Africa. Another step in advance is to stretch across a river a number of ropes, made of rushes or leathern thongs, secured on the opposite banks between trees and posts, and connected and covered, so as to form a slight bridge. This method is practised in some of the mountainous districts of South America. The ropes are formed of thongs of ox-hide, consisting of several strands, about six or eight inches in thickness, and across these, in a transverse direction, sticks are laid, and these are covered with a flooring of branches of trees. In other cases, an ox-hide rope is extended from one side of the river to the other, and is secured to each bank by means of strong posts. On one side is a kind of wheel, or winch, to straighten or slacken the rope, from which hangs, by a clue at each end, a kind of leathern hammock, capable of holding a man. A rope fastened to either clue, and extended to each side of the river, is used for drawing the hammock to the side intended. A push at its first setting-off sends it quickly to the other side. Mules are carried over in this way.

Another mode of bridge-building is to construct piers of stone, at a short distance from each other, to be spanned by single stones or slabs, or by beams of timber. When this kind of bridge is used for shallow streams, and is composed of rough stones, without mortar, the operation is simple; but in deep and rapid streams, the construction of piers of hewn stone indicates a considerable advance in the useful arts, because a proper foundation for each pier is required. The bridge over the Euphrates at Babylon

was thus formed, and this method of construction is common in different parts of China.

In this singularly interesting country, also, the arch—that grand feature in a bridge—has been in use for many ages; but the Chinese—in many cases, at least—do not seem to have constructed arched bridges of sufficient strength to bear carriages. The arch, however, covers the gateways in the great wall; and Kircher speaks of stone bridges in China, three and four miles long, and of an arch of the incredible span of six hundred feet. In Egypt and India, the arch does not seem to have been known, or applied to the construction of a bridge; for although brick arches are said to have been found buried in the tombs of Thebes, yet the ancient Egyptians never built a permanent bridge across the Nile. There is no trace of the arch in the ancient works of Persia or Phœnicia; and even the Greeks, who created a school of architecture and sculpture, have a very doubtful claim to the knowledge of the arch. When Pericles adorned the city of Athens with splendid edifices, a stone bridge was not constructed over the small river Cephisus, although upon the most frequented road to that city. It is to the Romans that the western world is indebted for this useful invention. There is great uncertainty as to the time when the Romans first used the arch. If the *cloacæ* of Rome were constructed in the time of the elder Tarquin, the use of arches must have been then well known. Some writers suppose that the Romans derived their knowledge of the arch from the Tuscans, a colony of Dorians, and hence intimately connected with Greece. Some of the ancient Roman bridges still exist. (See Fig. 265.) One of the most magnificent was built by Augustus, near Narni, on the

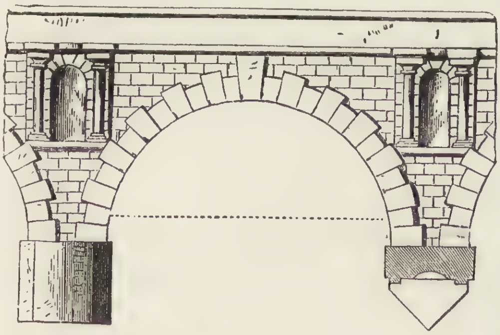


Fig. 265. PONS SENATORIUS.
(Now called Sancta Maria.)

road from Rome to Loretto. It consisted of four arches, the first of 75 feet span, and 102 feet height; the spans of the other arches were 135, 114, and 142 feet, respectively. In the provinces, the Romans built many magnificent bridges. The bridge of Merida, on the river Guadiana, is said to have been 1,300 paces long, with 64 arches. But, perhaps, the most magnificent of all the Roman bridges, and one of the noblest monuments of antiquity, is the bridge of Alcantara, on the Tagus, consisting of 6 arches: the whole length is 670 Spanish feet, and the height, from the bed of the river to the roadway, is 205 feet.

From the destruction of the Roman empire to the establishment of modern Europe, there are no bridges of importance, except those fine works by the Moors in Spain, particularly the bridge of Cordova, over the Guadalquiver. When the arts began to revive in Europe, they were chiefly directed to religious structures. There was little security for travellers, especially in passing rivers, where they were exposed to violent exactions by banditti and robber knights. To put a stop to these disorders, sundry persons formed themselves into fraternities, which became a religious order, under the title of the *Brethren of the Bridge*. The object of this institution was to build bridges, establish ferry-boats, and receive travellers into hospitals on the shores of rivers. The first establishment was upon the Durance, at a dangerous spot named *Maupas;* but, in consequence of the accommodation arising from this establishment, it acquired the name of *Bonpas*. It is related that St. Benezet, who proposed and directed the building of the bridge of Avignon, was a shepherd; and that, at the age of twelve, he was supernaturally commanded to quit his flock, and undertake this enterprise; that he arrived at Avignon at the time when the bishop was preaching to fortify the minds of the people against an eclipse of the sun, which was to happen the same day. Benezet raised his voice in the church, and said that he was come to build a bridge. His proposal was accepted by the people with applause, but rejected by the magistrates and some others. As it was at that time an act of piety to build a bridge, and Avignon was then a popular republic, the people prevailed; and every one contributed to the good work, some by money, and some by labour, all under the direction of Benezet, aided by the Brethren. Upon the third pier was erected a chapel to St. Nicholas, protector of those who navigate rivers. This was done in 1184, after the death of Benezet, who established a conventual house and a hospital, leaving the Brethren to continue the work of the bridge. This bridge was commenced in 1176, and completed in 1188. It was composed of 18 arches. In 1385, during the contentions of the popes, some of its arches were destroyed: three others fell in 1602, from the neglect of repairing a fallen arch. In 1670, the frost was so great that the Rhone, for several weeks, bore the heaviest carriages: when the thaw followed, the piers were destroyed, except the third, which bore the chapel. The fine bridges of Lyons, of 20 arches, and St. Esprit, of 19, were erected by the surviving Brethren of the Bridge.

According to Perronet, an arch of 150 French feet (equal to 160 English feet) span was erected at Verona, in 1354; and, in 1454, one of 183.8 English feet span, and 70.6 feet of rise from the springing, at Vielle Brionde, upon the river Allier, in France. There are also many fine bridges in Italy. The finest in Venice is the Rialto, of $98\frac{1}{2}$ feet span, and 23 feet rise: it was designed by Michael Angelo, and

erected between 1588 and 1591. There are no fewer than 339 bridges in Venice.

Some very beautiful bridges have been erected in France during the last two centuries. Plans and descriptions of some of those erected between 1750 and 1772 are given by Perronet. Many of them are of great simplicity and elegance. The bridge erected over the Seine at Neuilly by Perronet is said to be his finest work. It consists of 5 arches, each 128.2 feet (English) span, and 32 feet rise. The breadth, including the parapets, is 48 feet. It was commenced in April, 1768, and opened in October, 1773; the masonry was completed in 1774; the roads, and other operations connected with it were finished in 1780.

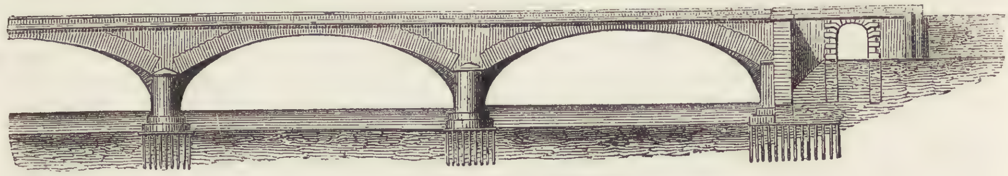


Fig. 266. PONT DE NEUILLY.

The art of bridge-building in England kept pace with its progress on the continent. The singular bridge at Croyland, in Lincolnshire, (Fig. 267) is said to have been built in 860. It has three distinct approaches, formed by three segments of a circle,

Fig. 267. CROYLAND BRIDGE.

which, meeting in the middle, form pointed arches, their bases or abutments standing upon the points of an equilateral triangle.

Old London Bridge was commenced in the reign of Henry II., under the direction of Peter of Colchester, in 1176, the same year that the bridge of Avignon was begun. The French bridge was completed in twelve years: the erection of the English bridge occupied eighty-three; but this arose from the interruptions which must be experienced in a river where the tide rises twice every day, from 13 to 18 feet. The piles were principally of elm, and remained for six centuries without material decay, although a portion of the bridge fell, and was rebuilt, about one hundred years after it was begun. The stone bridge at Newcastle-upon-Tyne (built in 1281), and that over the Medway, at Rochester, consisting of 11 arches, were erected about the same time as the bridges of St. Esprit and Lyons, already noticed. During several centuries there were houses along each side of London Bridge; but these were removed in 1758. The middle pier was also taken away. The piles were drawn by a very powerful screw, commonly used for lifting the wheels of the water-works; and the space including the two adjacent arches converted into one arch, of 72 feet span. The remaining old arches were very narrow, and the piers of vast size, being from 15 to 25 feet in thickness above the sterlings. Many of the old English bridges were fortified with gateways. In 1636, Inigo Jones designed a bridge, which was erected at Llanwst, in Denbighshire, consisting of 3 arches, segments of circles: the middle one is 58 feet span, and rises 17 feet; the piers are 10 feet thick, and the breadth of the soffit of the middle arch is 14 feet. The arch-stones of the largest arch are only 18 inches deep; the covering over them is small, and the approaches are very steep, so that the bridge has a very light appearance.

In 1738, the situation of the present decayed structure, Westminster Bridge, was agreed on, and Mr. Labalye, the architect, was allowed, after much doubt and difficulty on the part of the commissioners appointed by Parliament, to lay the foundations of the piers in caissons, or chests, filled with masonry, of a form and size suitable to the piers intended to be erected, and floated to the sites of the piers, where they were sunk, the bed of the river having been previously levelled by dredging. This method was adopted instead of placing the foundations upon piles, in the ancient manner, cut off above the level of low water, or using batterdeaux or cofferdams formed around the foundations, and pumping the water from the inside, as had been done in more modern times. The bridge was surmounted by a lofty parapet, the object of which was to secure a sufficient weight of masonry to keep the caissons in place. Labalye states that this bridge contained twice the number of cubic feet of stone used in St. Paul's Cathedral. The bridge was finished in 1747, and was about to be opened, when the following accident happened:—Some workmen employed to get gravel out of the bed of the river, to cover the roadway of the bridge, finding some very suitable near the third pier on the western side of the centre arch, excavated considerably lower than the foundation, and too near it; consequently, the gravel escaped from under the platform, and the pier sunk so much as to make it necessary to take down the two arches which rested upon it. The opening of

the bridge was therefore delayed until the 18th November, 1750. This bridge consists of 13 large and 2 small arches: their forms are semicircular; the middle one is 76 feet span, and the breadth over the parapets 44 feet. The system of building on caissons, as illustrated by the subsequent history of this bridge, has proved a failure, and has not been adopted in England. After the removal of old London Bridge, the bed of the river, on which the caissons rest, became undermined so much by the body of water, and increased velocity of the tide, that some of the piers gave way in 1846, so that in August of that year it was found necessary to close the bridge. Portions of the heavy masonry about it were removed, and the bridge itself was considerably lowered. It now remains standing, as it were, upon crutches, awaiting its dissolution. Mr. Barry has furnished a design for a new bridge, which will probably be adopted when the new Palace at Westminster shall be completed.

Blackfriars Bridge was commenced from a design by Robert Mylne, about ten years after the completion of Westminster Bridge. It consists of 9 elliptical arches. The middle arch is 100 feet span; the length of the bridge is 995 feet from wharf to wharf; the breadth across the bridge is 43 feet 6 inches. The piers were built in caissons; but piles were previously driven for the caissons to rest upon. The arches being of wider span and of an elliptical form, and the piers of proportionally less thickness, and having less masonry over the top of the arches, this bridge has a much lighter appearance than that of Westminster. The expense of Blackfriars Bridge, including the purchase of premises, was about 260,000*l.*; that of the building was only 170,000*l.* Westminster Bridge cost about 400,000*l.* Blackfriars Bridge was made passable as a bridle-way on the 19th November, 1768, and was generally opened on the 19th November, 1769. There was a toll of one halfpenny for every foot passenger, and one penny on Sundays, until the 22d June, 1785, when Government bought the toll, and made the bridge free. A few years ago, the bridge was lowered, and the open balustrade removed.

It is impossible in this brief sketch to notice the various bridges erected in modern times in Great Britain and Ireland. Some of them will be incidentally noticed in the different sections of this article. We cannot, however, refrain from giving a few details respecting the beautiful bridge which has taken the place of old London Bridge.

The old method of laying the foundations of piers, which was introduced soon after the Conquest, was very defective, and was particularly exemplified in the old London Bridge. "The masonry commenced above low-water mark, being supported on piles, which would have been exposed to the destructive alternation of moisture and dryness, with the access of air, if they had not been defended by other piles, forming projections, partly filled with stone, and denominated *sterlings*, which, in their turn, occasionally required the support and defence of new piles surrounding them, since they were not easily removed when they decayed; so that, by degrees, a great interruption was occasioned by the breadth of the piers, thus augmented, requiring, for the transmission of the water, an increase of velocity, which was not only inconvenient to the navigation, but also carried away the bed of the river under the arches and immediately below the bridge, making deep pools or excavations, which required from time to time to be filled up with rubble-stones; while the materials which had been carried away by the stream were deposited a little lower down, in shoals, and very much interfered with the navigation of the river." From these circumstances, as well as from the effects of time and decay, it happened that the repairs of the old London Bridge often amounted, for many years together, to 4,000*l.* a-year. "It is true that the fall produced the trifling advantage of enabling the London water-works to employ more of the force of the tide in raising water for the use of the city; and this right being established as a legal privilege, long delayed the improvements which might otherwise have been attempted for the benefit of the navigation of the river. The interest of the proprietors of the water-works had been valued at 125,000*l.*, and it had been estimated that 50,000*l.* would be required for the erection of steam-engines to supply their place; while, on the other hand, from thirty to forty persons, on an average, perished annually, from the dangers of the fall under the bridge."

The consequence of removing the centre pier was somewhat to diminish the fall; but it was found necessary to obstruct the channel again, in order that the stream might have force enough for the water-works. But it was very difficult to secure the bottom from the effects of the increased velocity under the arch. A number of strong beams were fixed firmly across the bed of the river; but only two of them remained for any length of time, and the materials carried away were deposited below the middle arch, so as to form a shoal which was only sixteen inches below the surface at low water.

At length, after the bridge had been for more than six hundred years exposed to the constant action of a rapid current, it was determined to erect a new bridge. The loss of life and property was frequent, in consequence of the great velocity with which barges and smaller craft were carried by the stream through its arches, and of their descent, by means of a considerable fall, from one level to another. In 1823, an Act was obtained for rebuilding the bridge, and for making suitable approaches to it. John Rennie was appointed architect; but, as he died before the bridge was begun, the execution of his plan was confided to his son, Sir John Rennie. The new bridge, consisting of five elliptical arches, was intended to be on the site of the old one, and to correspond with the old approaches. It was, however, afterwards determined to construct it 180 feet higher up the river, so as to avoid the steep ascent of Fish Street-hill. The first pile of a cofferdam for the south pier was driven on the 15th March, 1824, and the first cofferdam was completed on the 27th April,

1825. It consisted of three rows of piles, dressed in the joints, and shod with iron; and many of them were 80 or 90 feet long. The first stone of the bridge was laid on the 15th June. The foundations of the piers are of wood, piles of beech being first driven in the interior of the dam, to a depth of nearly 20 feet, in the stiff blue clay which forms the natural bed of the river; two rows of horizontal sleepers, about 12 inches square, were then laid on the head of these piles, and covered with beech planking, 6 inches thick, on which the lowermost course of masonry was laid.

The obstruction caused by the works of the new bridge rendered it necessary to throw two of the small arches of the old bridge at each end into one, which was done in about six weeks.

The centerings for supporting the arches of the new bridge were required to be of great strength, because the flatness of an elliptical arch produces a greater load on the centering, while building, than the semicircular arch does. Each centre consisted of ten frames, or ribs, supported at the two ends on piles driven into the bed of the river. These frames were boarded over on the top with stout planks. The arches, being unequally wide, required four sets of centres, each containing nearly 800 tons of timber. The first arch was keyed in on the 4th August 1827, and the last on the 10th November, 1828. Instead of filling up the spandrels of the arches with loose rubble-work, according to the usual practice, longitudinal or hance walls were built over the arches, and over these large blocks of stone were bedded, surmounted by heavy stone landings, on which is a course of cement, and over that the roadway. The approach from the city side is brought to the level of the bridge by a series of land arches in continuation of the bridge. The bridge was completed on the 31st July, 1831. It consists of five elliptical arches: the centre arch is 152 feet span, with a rise of $29\frac{1}{2}$ feet above high-water mark. The two arches next the centre are 140 feet span, with a rise of $27\frac{1}{2}$ feet; and the two abutment arches are 130 feet span, with a rise of $24\frac{1}{2}$ feet. The piers are solid, and rectangular in form. The great diminution in masonry work, in consequence of the form of the arches, allowed the piers to be greatly diminished in size. The line of roadway is a segment of a very large circle, the rise being only 1 in 132. The abutments are each 73 feet wide at the base, and spread out backward, so as to sustain the thrust of the bridge with best effect. The length of the bridge, from the extremities of the abutments, is 982 feet, and, within the abutments, 728 feet. The roadway is 53 feet between the parapets, being 8 feet wider than the old bridge, and 11 feet wider than any other bridge on the Thames. The foot-ways occupy 9 feet each, and the carriage-way 35 feet. The bridge is of the finest granite, from the quarries of Aberdeen, Heytor, and Penryn. The total quantity of stone was about 120,000 tons.

Section II.—Theory of Stone Bridges.

The theoretical principles of stone bridges contain the mathematical demonstrations of the properties of arches, the thickness of the piers, the force of the water against them, and other abstruse but necessary calculations. This branch of the subject, which has exercised the talents and ingenuity of some of the greatest mathematicians in modern times, is not sufficiently elementary for the present work; but it may be interesting to give a short abstract of Professor Moseley's theory of the arch, chiefly abridged from Mr. Weale's beautiful work, already referred to, with occasional reference to the accomplished Professor's popular works, entitled, "Illustrations of Mechanics," third edition, London, 1846, and "Mechanics applied to the Arts," third edition, London, 1847. We will, however, first describe the various parts of an arch.

An arch may be defined as a collection of wedge-formed bodies, named *voussoirs,* or *arch-stones, v v,* Fig. 268, the first and last of which are sustained by a support or abutment, A B, while the intermediate ones are sustained in their positions by their mutual pressures, and by the adhesion of the cement interposed between their surfaces. The centre voussoir, *k,* or that in the highest part or *crown,* C, of the arch, is called the *key-stone.* The inferior surface of the arch, *s f h f s,* is called its *intrados,* and sometimes its *soffit*; but this latter term is also occasionally restricted to the under surface of the arch, *h,* at its key-stone or crown. *s f f s* are the *flanks* of the arch. The exterior surface, *e C d,* is called its *extrados,* or *back.* The points *s s,* where the intrados meets the abutment, are called the *springings,* their horizontal direction, *s i s,* the *span,* and the distance *i h* the *rise* or *height* of the arch.

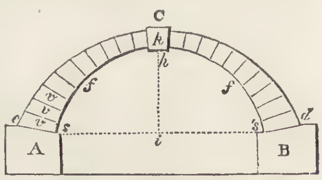


Fig. 268.

Such a structure, or, indeed, any structure, built up with uncemented stones, may fall, either by the opening of some of the joints, causing the stones to *turn* on the edges of one another after the manner of a hinge, or by the stones slipping upon one another.

These two cases are represented in the following figures. In Fig. 269, an arch is falling by the turning of its voussoirs at the crown upon the upper edges of one another, and, at the haunches, upon their lower edges. In Fig. 270, the arch falls by the sliding of the arch-stones near the abutment downwards, and by the sliding of those near the crown upwards. The latter case is, however, of rare occurrence; for such is the friction of the surfaces of the stones used in construction, that their slipping upon one another is probably unknown in practice; yet, until within the last few years, the slipping of the voussoirs upon one

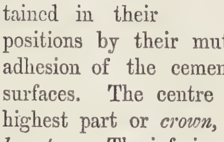


Fig. 269.

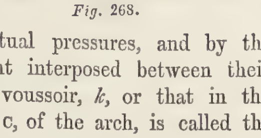


Fig. 270.

another was considered to involve the whole question of the stability of the arch.

Let a structure, M N L K, Fig. 271, composed of a single row of uncemented stones, of any forms, and placed under any given circumstances of pressure, be intersected by a surface 1, 2, and let the resultant *a* A of all the forces which act upon one of the parts, M N 2 1, be taken. Then let this intersecting surface change its form and position, so as to coincide in succession with all the common surfaces of contact, 3 4, 5 6, 7 8, 9 10, of the stones which compose the structure, and let *b* B, *c* C, *d* D, *e* E, be the resultants, similarly taken with *a* A, which correspond to those several planes of intersection. In each such position of the intersecting surface, the resultant spoken of, having its direction produced, will intersect that surface either *within* the mass of the structure, or, when that surface is produced, *without* it. If it intersect it *without* the mass of the structure, then the *whole* pressure upon one of the parts, acting in the direction of this resultant, will cause that part to turn over upon the edge of its common surface of contact with the other part; if it intersect it *within* the mass of the structure, it will not. Thus, if the direction of the resultant of the forces acting upon the part M N 1 2 had been *a′* A′, not intersecting the surface of contact 1 2 *within* the mass of the structure, but supposed to be produced beyond it into *a′*; then the whole pressure upon this part acting in *a′*A would have caused it to turn upon the edge 2 of the surface of contact 1 2. So, also, if the resultant had been in *a″* A″, then it would have caused the mass to revolve upon the edge 1. But the resultant having the direction *a* A, the mass will not be made to revolve on either edge of the surface of contact 1 2.

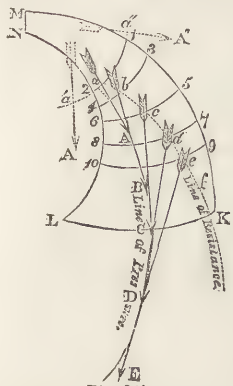


Fig. 271.

Thus, the condition that no two parts of the mass should be made by the insistent pressures to turn over upon their common surfaces of contact, is involved in this other, that the direction of the resultant, taken in respect to every position of the intersecting surface, shall intersect that surface actually within the mass of the structure.

If the intersecting surface be imagined to take up an infinite number of other positions, 1 2, 3 4, 5 6, &c., and the intersections with it, *a b c d*, &c. of the directions of all the corresponding resultants be found, the curve line *a b c d e f*, joining these points of intersection, is named by Professor Moseley the *line of resistance.* This line can be completely determined by the methods of analysis, in respect to a structure of any given geometrical form, having its parts in contact by surfaces also of given geometrical forms. And conversely, the form of this line being assumed, and the direction which it shall have through any proposed structure, the geometrical form of that structure may be determined, subject to these conditions. Or lastly, certain conditions being assumed, both as it regards the form of the structure and its line of resistance, all that is necessary to the existence of these assumed conditions may be found. Let the structure A B C D, Fig. 272, have for its line of resistance the line P Q. Now, it is evident that if this line cut the surface M N of any section of the mass in a point *n*, without the surface of the mass, then the resultant of the pressures upon the mass C M N will cut through *n*, and cause this portion of the mass to revolve about the nearest point N of the intersection of the surface of section M N with the surface of the structure.

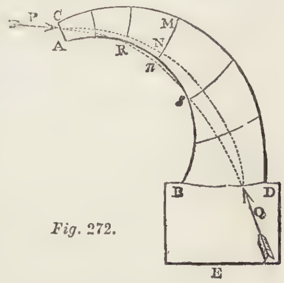


Fig. 272.

It is therefore a condition of the equilibrium, that the line of resistance shall intersect the common surface of contact of each two contiguous portions of the structure actually within the mass of the structure; or, in other words, that it shall actually go through each joint of the structure, avoiding none: this condition being necessary, that no two portions of the structure may revolve on the edges of their common surface of contact.

Let us borrow from the same competent authority another illustration of this great condition of the equilibrium of an edifice. Let the extreme stone, Fig. 273, of an edifice of uncemented stones have impressed upon it any given force, P. In addition to this force, the stone is acted upon by gravity, which may be supposed to be collected in its centre of gravity. The resultant of these two forces will represent the whole force by which the first stone is pressed upon the second. If this resultant have its direction anywhere within the edges of the joint or surface of contact of the first stone with the second, the one will rest upon the other; if not, it will turn over upon it. The second stone may be considered to have its upper surface acted upon by the resultant force just spoken of, and this to be the only force pressing it downwards, besides its own weight, collected in its centre of gravity. If, then, a second resultant be taken, being that of two forces, of which the first resultant is one, and the weight of the second stone the other, then this second resultant will be that force by which the second stone may be supposed to be pressed upon the third. If its direction lie within the edges of the joint of the second and third stones, the second will rest upon the third; if not, the superstructure will turn upon the third stone. So, also, if a third resultant be taken, being that of two forces, of which one is the second resultant, and

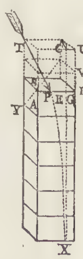


Fig. 273.

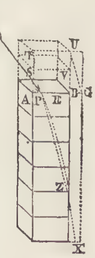


Fig. 274.

the other the weight of the third stone, then this third resultant will be that force by which the third stone is pressed upon the fourth; and the conditions of the equilibrium of this third stone are, that this resultant shall have its direction within the edges of the joint of the third and fourth stones: and so on of the rest. If we now suppose that the intersections of all these resultants with the planes of the joints of the successive stones are found, by mathematical investigation, and a line be drawn through all these points of intersection, we get the line of resistance before spoken of. If this line, which is a curve, have its direction anywhere beyond the joints of the stones, the edifice will be overthrown at such joints; but if the curve nowhere lie without the mass of the edifice, it will nowhere be overthrown by the turning of its stones.

But there is a second condition necessary to the stability of the structure. Its surfaces of contact must nowhere slip upon one another. That this condition may be satisfied, the resultant corresponding to each surface of contact must have its direction within certain limits. In Fig. 271, the line A B C D E, formed at the points of the consecutive intersections of the resultants *a* A, *b* B, *c* C, *d* D, &c., is termed the *line of pressure*. Its geometrical form may be determined under the same circumstances as that of the line of resistance. A straight line, *c* C, drawn from the point *c*, where the line of resistance *a b c d* intersects any joint 5 6 of the structure, so as to touch the line of pressure A B C D, will determine the direction of the resultant pressure upon that joint: if it lie within a cone defined by Professor Moseley as a right cone, having the normal to the common surface of contact at the point of intersection of the resultant for its axis, and having for its vertical angle twice that whose tangent is the coefficient of friction of the surfaces, the structure will not slip upon that joint; if it lie without it, it will.

Thus, the whole theory of the equilibrium of any structure is involved in the determination with respect to that structure of these two lines,—the line of resistance, and the line of pressure: the former determining the point of application of the resultant of the pressures upon each of the surfaces of contact of the system; the latter, the direction of that resultant.

In an upright pier or wall, the line of resistance is a hyperbola, the position and magnitude of which may be determined by construction. Resolve the force P, Fig. 273, which acts upon the summit of the pier, into two others, one of which is in a vertical and the other in a horizontal direction. Calculate the height of a mass which, being of the same substance and the same thickness as the pier, shall have a weight equal to the vertical force of these two, and let this height be B U. Calculate in like manner the height of a mass whose weight shall equal the horizontal force, and let this height be A S. (The dotted lines, Fig. 273, represent these two imaginary masses.) Take E, the centre of the width of the pier, and set off E G, equal to A S. Then draw the vertical G C. C will be the centre of the hyperbola, and the vertical C E X will be its asymptote. Now, the curve of a hyperbola always approaches, but never touches, its asymptote. The curve of resistance always, then, approaches, but never touches, the line C X; and if this line lie, as in the figure, within the mass of the sphere, then the line of resistance, never passing the line C X, can never cut the outward surface of the pier; and, however tall it may be, the pier can never be overthrown by the action of this force. It is also a remarkable feature of the theory, that the pier will bear this insistent pressure P wherever in A G it is applied parallel to its present direction; the position of the centre of the hyperbola, C, not being changed by any alteration in the point of application of that pressure, but only in its magnitude.

Professor Moseley also gives the following method for determining the greatest height to which a pier can be built, so as to sustain a given pressure upon its summit. If A E, Fig. 273, be greater than half the width of the pier, or if G lie beyond B, then there will be some point in the outward surface or extrados of the pier where the line of resistance will cut it; and there will therefore be a certain height beyond which the pier cannot be carried without being overthrown. This height is thus determined. Let P, Fig. 274, be the point where the insistent pressure intersects the summit of the pier, and let A S, and A T, and E G be taken as before; join U G, and through P draw P Z, parallel to U G. Z will be the point where the line of resistance cuts the extrados, and will indicate the greatest height to which the pier can be carried without being overthrown; or, if it can be carried higher, then is this the point to which an inclined buttress should be built to support it.

The details which have been given will enable the reader to form a general idea of the application of the theory of the line of resistance to the conditions of the equilibrium of the arch. It is a general condition that this line, R Q A Q' R, Fig. 275, (which represents an arch having the joints of its voussoirs perpendicular to the intrados, as they are usually made) touches the intrados or inner surface of the arch on both sides at its haunches, Q Q', and the extrados at the crown, in A, and that afterwards, at lower points, it cuts the extrados or outer surface of the arch at R R'. If some resistance, of an abutment or pier, be not opposed at this last point to the pressure, the whole of which acts there, the arch will be overthrown. If it be supported there by a pier, the line of resistance passes into the pier, and assumes a new character and direction; that direction having a general tendency towards the back or outer surface of the pier. If, by reason of the comparatively small height of the pier, the line of resistance does not anywhere reach the back of the pier, but intersects its base, the pier will stand. But if the height be

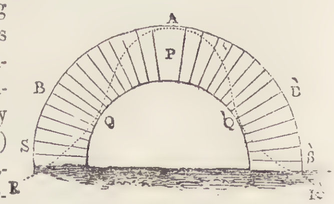


Fig. 275.

so great as to cause the line of resistance to cut the back of the pier at some point above its base, then the pier will be overthrown, and the arch will fall. When the arch falls, the line of resistance is made to cut the intrados at the points in the haunches, Q Q', where before it touched it. Hence, these points are called the *points of rupture.* The line of resistance thus cutting the intrados of the arch at these points, the direction of the whole pressure is made, at these points, to act beyond the joints of the stones there, so that it causes the stones to turn upon their lower edges, and to open at their upper edges. Besides touching the intrados at the haunches, it is another general characteristic of the line of resistance, in the state of the equilibrium of the arch, that it touches the extrados over the crown, at A, and that when the arch is falling, it is made to cut the extrados there: so that the pressure, there also, acting beyond the joints of the stones, causes them to turn, but, in this case, on their superior, instead of their inferior, edges. The arch then opens at the crown, A, at its intrados, and thus it falls, separating itself into four distinct parts as in Fig. 276. This is precisely what has been observed to be the process of the fall of the arch in experiments made for the purpose. M. Gauthey having occasion to destroy a bridge, caused one of its arches to be isolated from the rest; and the adhesion of the cement being sufficient to counteract the tendency of the pressure to rupture the piers, he caused them to be cut across. The whole then at once fell, the falling portion separating itself into four parts. Having constructed small arches of soft stone, and without cement, he loaded them until they fell. Their fall was always observed to be attended with the same circumstances. Before the arch finally yielded, the stone was observed to chip at the intrados, about the points Q Q', round which the upper portions of it finally revolved.

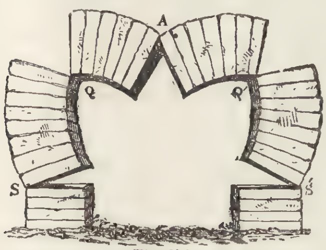


Fig. 276.

Professor Robison also relates some similar circumstances connected with the failure of a considerable arch. It had been built of an exceedingly soft and friable stone, and the arch-stones were too short. About a fortnight before it fell, chips were observed to be dropping off from the joints of the arch-stones, about ten feet on each side of the middle, and also from another place on one side of the arch, about twenty feet from its middle. The masons in the neighbourhood prognosticated its speedy downfall, and said it would separate in those places where the chips were breaking off. At length it fell; but it first split in the middle, and about fifteen or sixteen feet on each side, and also at the very springing of the arch. Immediately before the fall, a shivering or crackling noise was heard, and a great many chips dropped down from the middle, between the two places from whence they had dropped a fortnight before. The joints opened above at those new places more than two inches, and in the middle of the arch the joints opened below, and in about five minutes after this, the whole came down. Even this movement was plainly distinguishable into two parts. The crown sunk a little, and the haunches rose very sensibly, and in this state it hung for about half a minute. The arch-stones of the crown were hanging by their upper corners; when these splintered off, the whole fell down.

Professor Robison caused models of arches to be made in chalk, and loaded them at the crown until the line of pressure cut the extrados, and they fell. The material of the arch would of course be most likely to yield at those points where the line of resistance most nearly approaches the intrados; and in these experiments the chalk was observed to chip and fall off there before the final rupture. Having loaded his arches at the crown until they fell, he observed, however, that the points where the material began to yield were not precisely those where the rupture finally took place. This would necessarily be the case; for any variation in the least force which would support the semi-arch, if applied at its crown, would cause a corresponding change in the position of the points Q and Q', Fig. 275. Now, as the load on the crown is increased, this force is also increased, and the result is a variation in the form of the line of pressure, tending to carry its point of contact with the intrados lower down upon the arch. Accordingly, it was observed that the arch began to chip at a point about half-way between the crown and the point where the rupture finally took place.

It will be seen by a reference to Fig. 275, that above the points Q and Q' the direction of the line of resistance is such as to indicate a direction of the pressure which would produce in the arch-stones a tendency to slide downwards upon one another, while below that point the tendency is to slide upwards. Hence, it might be expected that when the *centre,* or wooden frame, used for supporting the arch-stones during the erection, was removed, the motion of the arch-stones[1] would be slightly downwards, in reference to those voussoirs which are above the points Q and Q, and upwards in reference to those which are below those points. This motion of the voussoirs among themselves, on the removal of the centre, produces what is called the *settlement* of the arch, and this settlement is observed to take place precisely under the circumstances above described. At the bridge of Nogent-sur-Seine, before removing the centre of the arch, Perronet caused three lines to be cut upon the face of it, (Fig. 277) one horizontally, immediately above the crown, and the other two lying obliquely from the extremities of this on either side, towards the springing of the arch. After the striking of the centre, these lines were observed greatly to have altered their

(1) The arch-stones would admit of some degree of motion among one another, by the yielding of the cement, or by reason of the closer degree of contact into which the additional pressure would bring them.

forms, and even their relative positions on the face of the arch. All of them had, from straight lines, become curves. The horizontal line had sunk throughout its whole length, its greatest deflexion being

Fig. 277.

immediately above the key; thus indicating a downward motion in all the voussoirs on which this line was traced. The oblique lines, too, had on either side deflected from their first position towards the intrados of the arch, or downwards, up to certain points, corresponding to Q and Q'; beneath these points the deflexion was from the intrados of the arch, or upwards. Thus, among the voussoirs on which the oblique lines were cut, there was shown to be a downward motion, in respect to those above the points corresponding to Q and Q', and an upward motion in respect to those beneath those points. The same phenomena were observed to attend the settlement of other great arches constructed by Perronet, especially those of the Pont de Neuilly.

An arch may be so loaded about its haunches as entirely to alter the direction of its line of resistance; in which case it will be overthrown as effectually as by the too great height or insufficient weight of its piers in respect to the load it bears on its crown. An excessive load on its haunches may entirely alter the line of resistance, so as to flatten it at the top, and give it two elbows on either side of the crown, causing it to cut the intrados instead of the extrados at the crown, and the extrados at two points a short distance on either side of the crown; the points where it touches the intrados being by this process thrown much lower down upon the arch. The arch will in this case fail by the rising of its crown and the falling in of its sides. The great art of arch-building consists in so loading the arch as to secure it against either of these contingencies.

Section III.—On the Practice of Bridge-Building.

The practice of bridge-building requires a large amount of knowledge on the part of the engineer or bridge-architect, and has reference to the *situation*, he *design* and the *materials* of the bridge, which of course may vary according to circumstances. The bridge itself has reference to the *foundations*, the *piers and abutments*, the *centres*, the *arches*, the *spandrels and wings*, the *parapets* and the *roadway*, which are also subject to great variation, according to the taste and skill of the architect, and the means at his disposal.

1. *The situation* of a bridge must be determined by local circumstances, as in a town by streets and in the country by the adjacent roads. In laying out a new line of road through a country, choice may often be made of the points for crossing rivers, and as a bridge must always be a very costly portion of the road, it may be expedient to go out of the direct line to places at which crossings may be most conveniently effected. In general, the best point upon a river for a bridge, is where the stream is narrowest, and where the banks are raised sufficiently to form natural approaches, and are solid enough to form natural abutments. There may, however, be exceptions to this. "Where a river is narrowest it is deepest and most rapid, and where the banks are high and consistent enough to form approaches and abutments to a bridge, the water will rise higher in floods than at any point lower down, where it may have more room laterally. Unless, therefore, the crossing can be effected in one span, reach or bay, so as to avoid a pier or piers, it may be less expensive, and more certain to build a longer bridge over a wider part, and to form artificial approaches and abutments, than to construct a sufficient and perfect bridge where nature has provided both approaches and abutments, and where the traject is shorter. It does not often occur moreover, that both banks of a river are high in the same place; and again, where one bank of a river is elevated or cliff-like and of good consistence, it is very likely to have been the means of reflecting or throwing the water off to act upon the opposite bank, and so have itself become the head of a reach, or the concave face of a bend, where the stream is very generally widest. When circumstances admit of a bridge over a river being in one span or reach, or of one bay, it is comparatively unimportant whether it be placed upon a bend of the river or not, if it be so contrived as to give sufficient head-way for craft where the channel is, or, in other words, where the water is deepest, which in a bend is most frequently on the concave side. When piers in the water way are determined to be necessary for an intended bridge, the site should be chosen where the course of the river is straight, so that the bridge may be placed at right angles to the thread of the stream, and that the piers may thereby intercept and divide the water in the least objectionable manner. In a running river, the longest part of a straight reach may be left above the bridge with advantage, whilst in a tidal river the bridge should be placed in such a manner as to give the stream at both ebb and flow all the advantage that can be obtained from the piers lying in the direction of the currents; and where, as it must be in most cases, the down stream is the strongest, and the ebb of longer duration, the proportion of the reach above and below a bridge should be determined accordingly."

2. *The design.* When the situation of a bridge has been determined, a careful survey must be made of it, and a plan be laid down of the channels and adjacent banks, and of the streets and roads to be connected at each end of the bridge. The plan should present an outline or representation upon a horizontal

(1) Professor Hosking's Essays and Treatises on the Practice and Architecture of Bridges, inserted in Mr. Weale's work, on the Theory and Practice of Bridges.

section of lines raised vertically from every point of the surface of the ground. A plan of the site, as from A to B, Fig. 278, laid down from measurements made along the bending line of the surface,

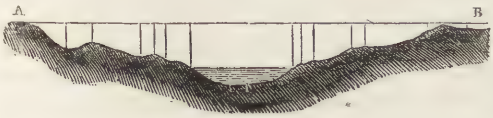


Fig. 278.

would give a much greater length than a plan upon a horizontal section of lines raised vertically from the surface of the ground to the straight horizontal line A B. Such a section must show the irregularities of the ground, the various substances of which the ground is composed, and the thickness vertically of each substance as far as it is necessary to ascertain it; that is, until a proper substance upon which to work has been found. This may be obtained by boring. In addition to the transverse section of the river, which is the direction to give the longitudinal elevation of the proposed bridge and its approaches, a longitudinal section of the river transversely of the bridge must be taken to show the declivity of its bed, and to exhibit any unsound strata that may lie near the proposed site. Upon both sections of the river, the ordinary depth of water in it, the highest level it ever attains, and the lowest to which it falls, should be ascertained and recorded, as also the velocity of the stream and the quantity of water passing down the river at all times and seasons of the year.

3. *The materials* of which bridges are constructed are various, such as *timber*, the art of combining which is known as CARPENTRY; *stone*, the working and setting of which is called MASONRY; *brick*, the composition of which is termed *brick-work; iron*, which is prepared by the founder, and fixed and fitted by the smith, and known as *iron-work*. "Although a bridge may be built almost entirely of timber, as indeed bridges are often built,—except as to the smith's work in the form of shoes, rings, hoops, straps, bolts, nuts, washers, spike and other nails, which the carpenter finds essential to the proper and efficient combination of his principal material;—the best timber bridges are those in which solidity and evenness of pressure, with power of resistance and retention, are given by piers and abutments of masonry or brick-work; and in like manner, what is called an iron-bridge, may be said to require that its piers and abutments, or other points of support, shall be of masonry, or of a combination of mason's work and brick-work. Bridges are built and in some cases most efficiently so, of brick-work alone; but, that a brick-bridge may be durable and sightly, it is almost always necessary, and it is always desirable, that some of the more exposed parts should be of stone. Masonry may stand alone in the composition of a bridge, but neither brick-work nor masonry alone, nor the two in combination, can be made to effect such objects as may be attained by the aid of the iron founder and smith, and indeed, of the carpenter with his timber."

But the chief material of a bridge must be determined by local circumstances, as one place may furnish one kind of material and not others; but timber must nevertheless be most extensively and variously applied, not only as a bridge-building material, but as an auxiliary in the erection of a bridge with other materials. Yet of all the materials used in bridge-building, timber is the most perishable, although modern science has contrived methods of protecting it from many of the causes of decay. Iron as a bridge-building material possesses many valuable properties. Its tenacity and power of resistance in a comparatively small bulk, allow works to be constructed and effects to be produced, which belong to no other available material. It is however greatly affected by change of temperature, and is hence unstable in framing. It is also injurious to the material which it thrusts against or is connected with, and it wastes away by oxidation and other chemical processes. As an auxiliary in bridge-building iron is second only to timber, and both iron and timber are necessary in bridge-building, although neither may enter into the composition of a structure. Stone, however, is pre-eminently the material for bridges, whether we regard its grandeur of effect, its power of resistance and endurance, its unyielding nature, its massiveness, its capability of being cut or wrought to any form, size or figure, and its retentiveness of the form given to it; it has scarcely any tendency to change in bulk from changes in temperature, and it is inaccessible to moisture. Its practical want of elasticity prevents it being disturbed by concussions, but being readily frangible, it can only be used and applied where it shall not be subjected to transverse strains. Hence it is unfit for beams or for bearing across over a void, and for situations where it is liable to disturbance from concussions. The inelasticity and frangibility of stone prevent a combination of parts by framing, as is done with timber and iron; but if the stone be cut up into pieces of certain forms previously arranged, as in the arch, it will carry a much greater weight than if thrown across the same space in the form of a beam or lintel; but the parts so arranged require the restraint of an extraneous tie, or a loading of the abutments and haunches not necessary to the level bearing across, and which a susceptibility of being framed would have obviated.

Brick must be regarded only as a substitute for stone, where stone cannot be obtained. Brick resembles stone in being practically incompressible and inflexible, but being prepared in small, regular and equal forms, it must be combined with cement or mortar, which, from its nature and mode of preparation, is yielding and liable to change until it has set and become perfectly dry. An arch turned with uncut bricks depends entirely on the mortar with which the bricks are packed, and is hence liable to change its form and become insecure while the mortar remains incompressible or less hard and unyielding than the substance of the brick. It is, however, not uncommon to strike the centering of brick arches before the mortar is properly set, in order, as is supposed,

to allow the materials to settle and consolidate by mutual pressure. This practice has probably led to the destruction of many of the large brick arches recently constructed on some lines of railway. A combination of brick and stone produces excellent results in bridges, the stone being introduced in chains and strings to assist in binding the brick-work, and in springing, blocking and coping courses and upon salient and exposed parts generally, and to receive and distribute pressure where it is greatest.

It may be stated as a general rule, that wherever the object to be attained in the use of a bridge can be effected by timber, the same end may be answered better and more effectually, both for use and durability with iron; and where the object proposed in the use of a bridge can be attained by the use of brick, the same thing can be done more effectually with stone; while iron and stone can often be applied where timber or brick could not be used. Probably in all cases where there is a choice between iron and stone, the latter will deserve the preference; but the art of constructing a bridge in the readiest, cheapest and simplest form will greatly depend on the facility of procuring materials. Bridges, like roads, canals and other means of transit, are often necessary to give value to the products of industry, and must be adapted in many cases, as in that of an infant community, a new colony, for example, to supply the want with the smallest expenditure of labour.

We come now to notice the practice of bridge building chiefly with reference to stone bridges, taking the several parts of the bridge in the order enumerated at the head of this section.

1. *The foundations* of a bridge consist of the underground work of the piers and abutments, and these require to be constructed with the utmost care in order to produce firm and solid bases whereon to carry up to any required height the various pedestals of support for the arches of the bridge. Alberti's distinction between the structure above-ground and the foundations of any building is applicable to bridges. He considered the foundation, not as a part of the structure itself, but as an artificial support on which the latter is to be placed; and remarks, that if the natural site of a building consisted of rock or other stratum equally hard with the material of which foundations are constructed, these would be unnecessary, and the building might be commenced and carried up without previous preparation of the bottom. Gauthey also remarks that the solidity of a bridge depends almost entirely on the manner in which its foundations are laid. When these are once properly arranged, the upper part may be erected either with simplicity or elegance, without impairing in any degree the durability of the structure. Experience has proved that many bridges either decay or are swept away by sudden floods, by reason of the defective mode of fixing their foundations, while very few suffer from an unskilful construction of the piers and arches.

In constructing the foundation of bridges which are to pass over roads or railways, the absence of water removes the greater part of the difficulty which is met with in spanning a wide and rapid stream; for if the bottom be unsound, the stability of the work may be ensured by driving piles, or by using concrete. In crossing narrow streams, the abutments may often be founded on dry land, or the course of the river may be turned and the piers constructed in the dry bed; but where none of these facilities are afforded, the bridge architect or engineer will have to contend against all the difficulties of operating in the midst of water.

In the ancient practice of bridge building, two methods were adopted for constructing the foundations. For shallow rivers stones were sunk to the bottom in strong baskets made of the pliable boughs or branches of trees; when this rude basket or caisson was sunk, stones were added until they were piled up to within a foot or 16 inches of the lowest water surface. In later times this plan was improved upon by forming wooden chests strongly hooped with iron, and constructing in them above-ground masses of masonry, which were sunk into the bed of the river. This method was practised by Labelye in the construction of Westminster, and by Mylne in the construction of Blackfriars bridges.

According to the second ancient method where strong currents existed, and it was necessary to construct the piers on dry ground, the plan adopted was to form the piers at some convenient distance from the river, in a range with the general direction of the stream, and at right angles with some good and direct approach previously selected, leading to and over the bridge, and when the bridge was completed to turn the course of the river by a new channel through the water way of the bridge. In Fig. 279 we have the plan of a bridge to be built in

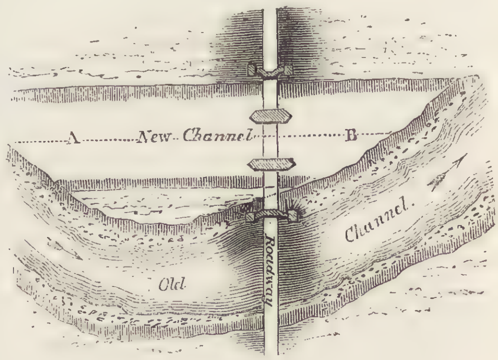


Fig. 279.

a neck of land formed by a bend of the river, which must afterwards be diverted from its course in the direction of the dotted line A B, and the roadway can be readily embanked across the old channel, which will be laid dry. Even where the course of the river is nearly straight, the difficulties and expense of constructing the piers in the water may be so great as to warrant the engineer in slightly turning the river as in Fig. 280. which shows the appearance of the diversion, the bridge having been built on dry land on one side of the old channel, thus affording the advan-

tage of a firm bottom at very moderate cost, compared with the other situation.

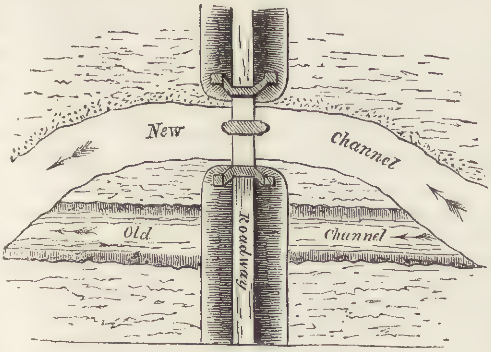


Fig. 280.

In the old bridges, if the bottom proved unsound, piles, 3 or 4 feet apart, were driven down over the site of the proposed piers; and instead of cutting off the pile heads evenly, and planking them over with timber, as is now done, it was customary to fill in between them with a species of coarse concrete,[1] which being brought to a level surface, formed the bed on which the first course of stone was placed. Another ancient method of using piles for building in water, and still used by the French, who call it *encaissement*, consisted in driving in main piles with sheet piling between them, secured and bound round with waling as in the modern coffer-dam, but only one row of piles was driven all round the space of the pier or abutment to be founded, and not a double row of piles to be filled with clay, as in a coffer-dam. The encaissement being formed, and the loose soil, &c. got out, a mass of concrete or dry rubble stones is thrown in until a sufficient foundation is formed reaching to the level of the water. After being allowed some time to settle, the dressed masonry is laid in courses upon the foundations thus formed. A design by Mr. Semple will illustrate this mode. In a river 6 feet deep he proposed to drive sheeting piles about 10 feet in length, to a depth of 4 feet in the ground all round the site of each pier, and to fill the space or coffer thus formed with a bed of concrete 6 feet in depth. The top of the concrete being level with the surface of summer low-water mark, the masonry was to be commenced therefrom and carried up to springing height clear of the water.

Mr. Hughes remarks that " on examining the foundations of old bridges, particularly in this country, they are all found to be extremely massive, and the piers were even carried up above water of a thickness quite incommensurate with the necessity of the case. On inspecting the masonry of their foundations, however, it is found that no very great attention has been paid to the regularity of courses, or to the perfection of beds and joints. Some of the strongest specimens of ancient masonry existing in this country, consist of a kind of building little superior to rubble walling, with this most important qualification, that the mortar is always of an excellent description, and in most cases by no means inferior in hardness and cohesiveness to the stone itself."[2] The mortar usually contained a great number of small stones or pebbles, some of them equal in size to a pigeon's egg, and was altogether much coarser than that used at the present day. Another point of difference between ancient and modern bridges is, that in modern times engineers form their bridges with as few arches as possible; the ancient structures " consisted of a long low series of culverts, hardly deserving the name of arches, with intervening piers often of greater thickness than the span of the arches they were built to support." The weight of such a bridge distributed over a great many points, such as the 20 or 30 piers sometimes built in the old bridges, each pier had scarcely more to support than its own weight. " The ancients in their bridges throughout the whole structure, substituted quantity for quality, that is to say, large masses of rough undressed masonry, or rubble, instead of the firm, compact and elegant piers of modern bridges, which, above the bed of the river at all events, are invariably built with the most durable stone, of well-squared dressed ashlar fronts, and suitable filling within." In some cases, however, there is no objection to these coarse and massive subaqueous structures; and provided they do not obstruct the free course of

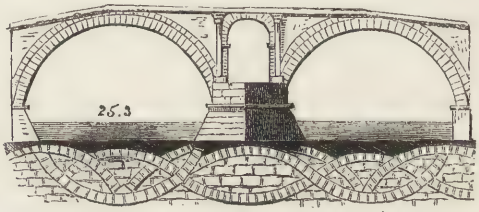


Fig. 281. THE BRIDGE OF FABRICIUS AT ROME.

the river, they may be of great advantage, especially in projecting sea piers and similar structures.

In modern times, the invention of the coffer-dam has enabled the engineer to secure a firm foundation in the bed of the river. Suppose a bridge is to be built over a river with 5 feet depth of water at the lowest summer floods; that the breadth of the waterway is great; and that it is impracticable to lay dry the bed by turning the course of the river. In such a case, the best method is to drive a coffer-dam all round the space which is to be occupied by the piers and abutments. The depth of water being 5 feet, suppose that of the unsound bottom to be 25 feet: the piles must not be less than 45 feet long, and must be driven into the solid ground as far as they will go, which may be from 8 to 10 feet. For such a depth of water, a double dam, with three rows of piles, will be required. The coffers between the rows of piles should be 6 or 7 feet apart, and filled with a retentive

(1) Called by the French *béton*. It seems now to be generally admitted, that the use of a concrete mixture composed of lime and coarse gravel, was common among the Romans. The use of concrete in modern times on a large scale, was introduced by Mr. Peter Semple, architect of a bridge over the Liffey at Dublin.

(2) A series of papers on the Foundations of Bridges. By T. Hughes, Civil Engineer,—inserted in Mr. Weale's work on the Theory, Practice, and Architecture of Bridges.

clay puddle, mixed with gravel and sand, or a portion of pounded chalk. All the water and soft material must then be got out of the dam. A steam-engine is used for clearing the space of water, and for keeping it dry during the progress of the building. The earth is removed from the coffer-dam by means of buckets, drawn up by windlasses erected on a temporary stage or platform across the dam, and the contents are discharged into barges alongside the dam. When the soft material has been removed, and the bottom is found to consist of hard gravel or clay, the building may be commenced, after sinking into it about two feet. Broad and large-bedded stones should be laid on the foundations, to give as much base with as few joints as possible for the superstructure to rest on. The first and second courses should be built with large stones, and, for the first few feet, with offsets, so that each course from the bottom may project all round at least six inches beyond the course immediately above. If, after the dam has been excavated, the bottom should appear unsound, piles must be driven all over the space to be occupied by the building, and extending about a foot beyond it. The piles may be of almost any kind of timber, such as Scotch fir, beech, elm, birch, &c. &c. eight or nine inches square, or round timber of this diameter: they should be driven in rows, from two to three feet apart, as far as they can be forced into the solid ground, or until each pile will not sink more than a quarter of an inch with twenty blows from a solid ram of 1,500 lbs. weight. When all the piles have been driven, their heads should be cut off quite level, and about a foot in depth being excavated between them, the space up to the level of the pile-heads should be filled with broken stones, grouted with good lime and sharp sand. A platform of oak, beech, or elm plank, from four to six inches thick, should then be placed across the pile-heads, and secured to them with spikes, bolts, or with trenails of hard wood. Another similar planking is usually laid across the first, and closely jointed thereto; and upon this upper platform the building, with brick or stone, is commenced. The masonry should be laid with offsets, and large stones should be used for the first and second courses.

This method of laying foundations by means of a coffer-dam and piling is very expensive. In situations where the river can be turned, a far less costly method may be adopted for giving stability to the unsound bottom. Mr. Hughes recommends that it be covered over entirely with cross-sleepers of Memel logs, and on these to lay a covering of planks closely jointed; while further security may be obtained by introducing inverted arches, above the planking, between the piers, and extending under each of the abutments. It will not be necessary to introduce a platform of timber to support the inverts, unless the ground be too soft to construct them upon it; and, in some cases, the platform without the inverts may be sufficient to carry the bridge. In many cases, concrete may be used as a substitute for piling, in order to secure a solid foundation. "The expense of laying a foundation of concrete, from four to six feet in depth, and extending about two feet round the space to be occupied by the building, ought, in all such cases, to be considered, and compared with the expense of piling, which will probably never be found more safe than a body of concrete, unless the bottom be so soft as to allow the concrete to sink into it, and thus entirely cease to support the building. For its durable and almost imperishable nature, concrete cannot be too much esteemed; and, besides being quite as safe, and, perhaps, more durable than piling, its cost will in most districts be found much less. Where the piers are to be built either of brick or stone, a great saving will be effected by the use of concrete underground, as the expense of this substance will in no case exceed one-third the price of any description of brick-work, and in some cases it may not cost more than a sixth."

It was Mr. Telford's practice, when the site of the foundations was unsafe, and the expense of driving piles through a very deep bed of loose material would be considerable, to lay an inverted arch between the piers and abutments. In other places, where the ground was more solid, but still doubtful, a pavement of broad stones was placed over the whole bottom, extending also under the abutments and wing-walls. These also were tied across the whole bottom by a row of the same description of broad-bedded stones, placed on edge; and this kind of pitching was often continued to the extent

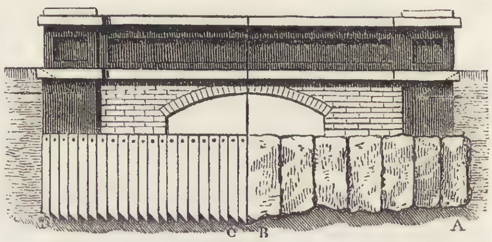


Fig. 282.

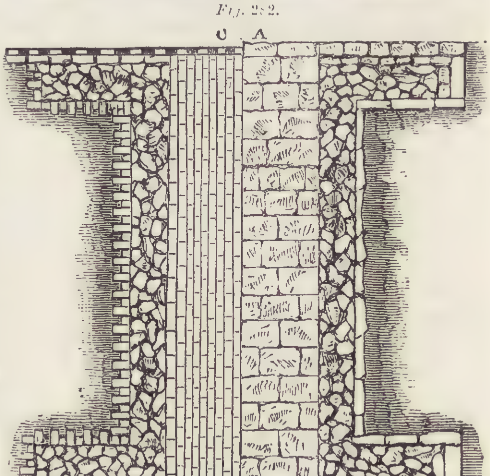


Fig. 283.

of the wing-walls, and then tied across by a row of the same stones, scabble-dressed, rough-shaped, jointed,

and set on edge, as at A B, Figs. 282, 283. When these stones could be procured in lengths of 6 or 7 feet, from 3 to 5 feet broad, and from 6 to 9 inches thick, Mr. Telford preferred them to timber as a covering. Where large stones could not be readily obtained, he directed a pitched bottom to be formed with stones of about two feet superficial area, and not less than a foot deep. These were pitched endwise, close-jointed throughout their whole depth, and set with considerable care; and they were never allowed to be set on sand or any material that could afterwards be carried away by the water. This pitching was usually secured at the end of the abutments and wing-walls by a longitudinal sleeper, placed along the outside, with sheeting piles driven down in front to a depth of from six to ten feet, according to the nature of the bottom. This method is shown at C D, Figs. 282, 283.

Sandy foundations present a great variety. The sand may be rounded or angular, the latter forming what is called a *sharp* sand; or the particles may be minute, as in *fine* sand, or very large, as when the sand approaches the nature of gravel. Sandy soils are also distinguished from each other by the proportions they contain of clay, or other earthy matter, which, in combination with the sand, is termed *silt*. Fine sharp sand is usually found in currents sufficiently rapid to carry away the particles of earthy and other matters, commonly deposited with the sand in still waters. When the currents are still more rapid, the beds may consist of gravel and sharp angular sand, with no silt. The stronger the current, the coarser the gravel, and the smaller the proportion of sand mixed with it. A quicksand is formed by the action of water on a bed of this material, whether of a silty or pure sandy nature; and the danger of its giving way, when any weight is placed upon a quicksand, arises from its tendency to escape with the water, and pass from under the pressure. If this can be prevented, the foundation is a good one; for sand or silt, in a state of rest, is remarkably solid, the smallest vacuities being filled with it. Thus, a quicksand surrounded by a strong and close encaissement of piling would be perfectly safe as a foundation. When there is any danger of the sinking of a structure in consequence of the lateral shifting of the sand, the first part of the foundation should consist of a timber platform resting upon the sand, and of sufficient area to extend two or three feet on each side beyond the base of the structure to be raised upon it. It may be laid with sleepers, ten inches wide, and six inches thick, placed at the distance of three feet apart, from centre to centre: these must be closely covered with four-inch-thick planks, closely jointed, and secured to the sleepers with trenails.

In rivers where there is very little current, and the sand bottom has a covering of two or three feet of clay, or heavy gravel, which is not liable to be disturbed by floods or other causes, a building may safely rest on a sand bottom, without the accompaniment of a platform. In other cases, an artificial covering may be placed over the sand, and thus prevent its disturbance. Such a covering may be found necessary after the erection of a bridge, to prevent a sandy or silty bottom from being carried away by the current, which is often increased in velocity by the contraction of the water-way. By covering the bottom with clay for a distance of sixty or seventy feet above and below the bridge, and then overlaying the clay with stones varying in weight from 200 lbs. downwards, the whole artificial covering not exceeding two feet in thickness, the further wasting of the bottom may be prevented. This plan was successfully adopted by Mr. Rennie in the case of the Lary Bridge at Plymouth.

Some idea of the method of forming a coffer-dam may be gathered from the following details. Suppose a bridge-pier is to be erected in a tide-river, where there is 10 feet depth of water at the lowest spring tides, and that the bottom consists of 12 feet loose gravel and sand, with clay underneath. If we suppose the depth at high water to be not less than 28 feet, (making the whole depth, from the surface of high water, through the loose bottom, down to the clay, 40 feet,) the coffer-dam must be formed of four rows of piles, and the clay puddle will occupy three distinct spaces, or *puddle-walls*, between the four rows of piles. The outer row of piles, to be driven down to within a foot of low-water mark, and 5 feet into the clay, must be 28 feet long; the two middle rows, also to be driven 5 feet into the bottom, and to stand 3 feet above high-water mark, must be 48 feet long; the inner row, to be driven to about 11 feet above low-water mark, and 5 feet into the clay, will be 38 feet. The clear breadth between each two rows of piles to be 6 feet; the outer row of piles to be half-logs, of 12 inches by 6 scantling; the middle row to be

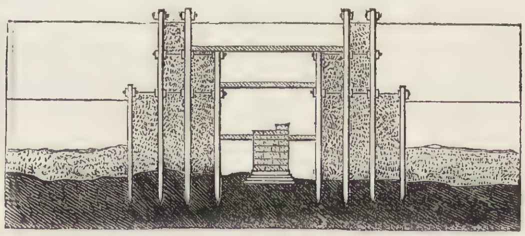


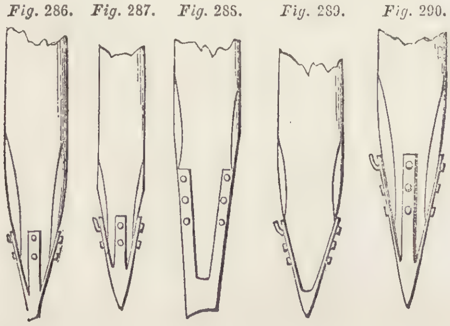
Fig. 284. TRANSVERSE SECTION OF COFFER-DAM.

Fig. 285. PLAN OF COFFER-DAM.

12-inch square logs, and the inner row to be 12 by 8 inches scantling. A double row of waling pieces to

be placed all round the top of the inner piles, as in Fig. 284, and to be connected by wrought-iron bolts, 1¼ inch square. Other lines of waling must be fixed round the coffer-dam, and connecting pieces must be introduced at intervals of 4 feet, from bolt to bolt, all round the dam. All the sand and gravel within the space to be occupied by the dam must be excavated, or it will permit the water to penetrate through; and this may be done by dredging before the piles are driven. In making the dam water-tight by puddling, clay alone should never be used, as it is subject to great changes, according to the alternations of heat and cold, drought and moisture. In very dry weather it will crack, and separate into irregular fragments, which will not unite again so as to form an adhesive water-tight substance. Mr. Hughes recommends 3 parts of pure clay, 2 of chalk, and 1 of fine gravel, as a good compound for filling the dam. These materials should be well mixed together, the chalk and clay chopped small, and no stone larger than a hen's egg allowed to pass amongst the gravel. It is usual in large dams to cover the top of the puddle with bricks, or with good strong gravel, grouted with lime, to the depth of a foot. All the piles used for the dam should be shod with wrought-iron shoes, not less than 10 lbs. each, and hooped with iron rings, three inches broad, and three-quarters of an inch thick, to prevent the timber from splintering or giving way under the driving. The following figures represent some varieties of iron shoes for piles.

Fig. 286. *Fig.* 287. *Fig.* 288. *Fig.* 289. *Fig.* 290.



In constructing a coffer-dam, the first operation is to drive the *guide-piles*, so called from being the first in each row, and thus serving as guides to the rest. They are usually placed about ten feet apart, and the barge or other vessel containing the pile engine should be moored stem and stern alongside the line of the intended dam. A ringing machine, and wooden monkey, of about 800 lbs. weight, are first used for driving; and when all the guide-piles of one row have been fixed, the walings should be fastened to them, and the intermediate piles, ten in number, between each pair of gauge-piles, may be driven down. When the piles cease to sink, after repeated blows from the monkey, a heavy iron ram, of 1,500 or 1,800 lbs. weight, with considerable fall, may be used to complete the driving. When the heads of the piles get bushy or besomy, they should be squared off, that the force of the blow may not be deadened.

The old methods of pile-driving, which were very slow and toilsome, have been superseded by

Fig. 291. RINGING-MACHINE USED AT THE PONT DE NEUILLY.

Nasmyth's Patent Steam Pile-driver, which may be easily made to perform 80 strokes per minute; and, in ordinary ground, piles of 14 inches square are driven at the rate of upwards of 10 feet per minute. The inventor says: "Instead of attempting to obtain high momentum from a small mass of iron falling from a great height, I employ the momentum resulting from a great mass falling with moderate velocity from a small height, (3 feet,) and, instead of having one blow per minute, I employ from 70 to 80 blows per minute. The result is that, while the pile is driven with ease and rapidity into the most rigid and resisting soil, the head of the pile is so little injured as to present a neater appearance after having been driven than at the commencement of the action. All this advantage arises simply from employing the mechanical force in its proper condition for the performance of the required duty. If we desire to split and shatter to splinters, let us give the blow from a small mass, travelling at the highest possible velocity; if, on the other hand, we desire to propel and push forward such a mass as a log of timber, let us do just the reverse, namely, give it a blow from a heavy mass, moving at a low velocity." The inventor justly remarks that, although we have equivalent mechanical forces in the case of

4 lbs. falling with a velocity of 4,000 feet per second,
and 4,000 lbs. falling with a velocity of 4 feet per second,

yet how very dissimilar are the effects of each, when

employed to perform such duties as that of driving a pile![1]

A remarkable application of the science of pneumatics has been made by Dr. Potts, in the construction of an apparatus for sinking foundations by means of atmospheric pressure, in deep water, moveable sands, mud, shingle, or bog. It consists in the use of hollow tubes, usually of cast-iron, of any size, and almost of any shape, which are sunk into their places by means of atmospheric pressure. The lower end of the tube is open, and being placed upon the ground, of whatever nature it may be, the air, water, or semi-fluid material in the inside is extracted by pumps, or by other means. When the more solid materials are removed, the air in the interior of the tubes is rarefied, by placing them in communication with large vessels from which the air has been previously withdrawn, by means of a pipe and stop-cock. As soon as the communication is effected, the air in the interior of the tubes rushes into the empty vessels, leaving the

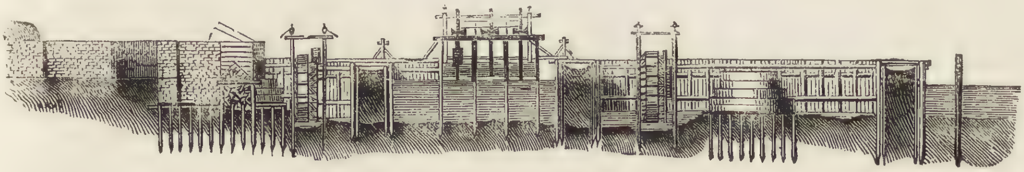


Fig. 292 SECTION OF COFFER-DAM AT NEUILLY.

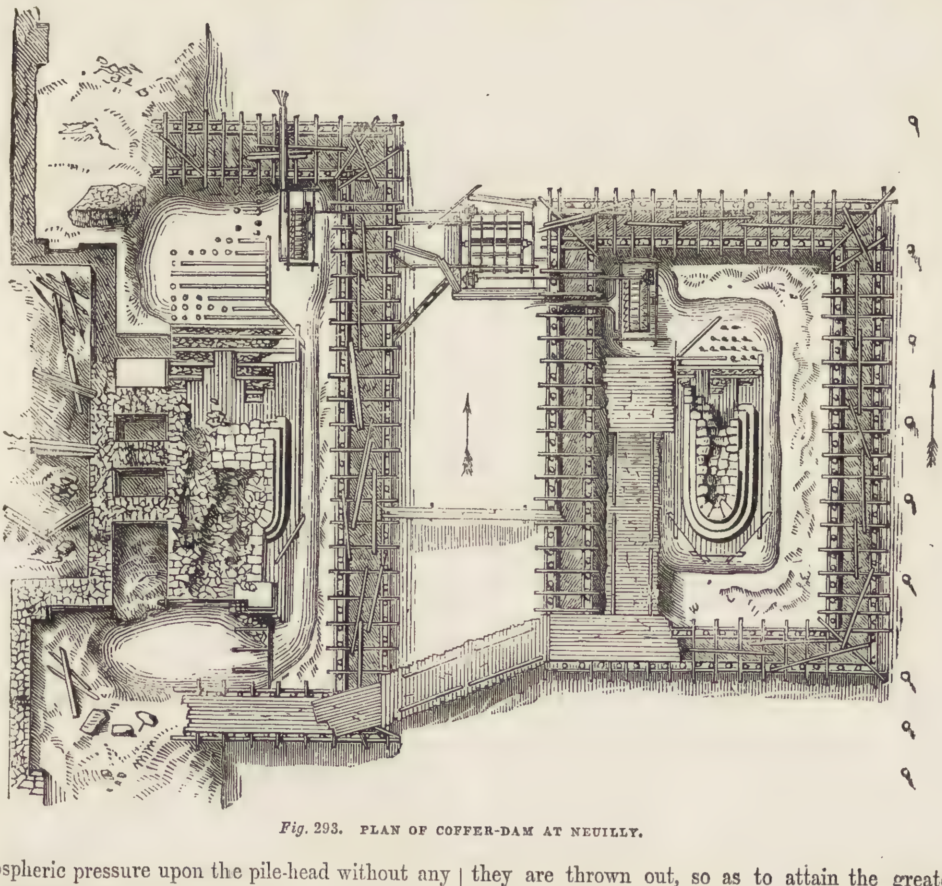


Fig. 293. PLAN OF COFFER-DAM AT NEUILLY.

atmospheric pressure upon the pile-head without any counteracting resistance. If the strata to be traversed be of a yielding semi-fluid nature, they are also acted upon by the same cause, and flow up into the tube or hollow pile, which at the same time descends with corresponding rapidity. The materials thus introduced are removed, or, if the strata be more resisting, they are thrown out, so as to attain the greatest possible rarefaction of the air; and the operation is repeated until the piles are fully driven. A succession of tubes may be placed upon the first by means of flanges or other joints, so that they may be driven of any length required.

The chief advantage of this system is, that no vibration is communicated to the ground, and the elasticity of the strata traversed is never brought into action. A remarkable illustration of its advantages in this respect occurred on the Goodwin Sands, where

(1) A full description of this machine, by the inventor, is given in Mr. David Scott's excellent work, entitled, "The Engineer and Machinist's Assistant," &c. Glasgow, Edinburgh, and London. 1847.

a tube 2 feet 6½ inches in diameter sunk to a depth of 32 feet 7 inches in 6 hours; whereas, a bar of iron, 3 inches in diameter, could not be driven more than 13 feet, at which depth it required 46 blows of a monkey weighing 10 cwt., falling through 10 feet, to advance it one inch. In such sandy soils, and sometimes, also, in clay soils, it is necessary to drive common piles with the large or butt-end downwards, to prevent the elasticity from forcing them up again.

These pneumatic piles have been used in the foundations of several railway-bridges. Those for Windsor Bridge were 5 and 6 feet in diameter; and at the present time Messrs. Fox and Henderson are about to put in the foundations of a bridge over the Medway, at Rochester, with cylinders 10 feet in diameter. With such colossal dimensions they cease to be piles, and become, in fact, caissons. When the hollow cylinders have been sunk, and the earth which has risen up into them been removed, they are filled up with concrete, and thus made equivalent to solid columns.[1]

The accompanying section and plan of the coffer-dam at Neuilly, Figs. 292 and 293, will convey a general idea of the arrangements of coffer-dams. The arrows represent the direction of the stream, which was taken advantage of for turning large water-wheels placed in the river, the motion of which, being communicated to pump-machinery within the dam, raised the waters thereof, and discharged them by means of shoots over the piles into the river. The works at the left of the figures are the land abutments, dammed in on the river side, and containing also the first pier. The complete coffer-dam to the right shows the second pier in progress. Temporary bridges of planking connect the dams with the land.

2. *The piers and abutments.* In the construction of a bridge it must be nearly always desirable to have the smallest possible number of points of support. "Piers in a waterway intercept the current and impede the navigation; they are most troublesome and expensive to found and form, and are most exposed to injury when they are formed. The object of the bridge itself—a convenient road over—being properly provided for, and the permanence of the structure being sufficiently considered, it is not too much to say that the aim and end of the bridge-builder should be to reduce the piers to the smallest possible number, consistently to a due regard to economy. Of all the bridges over the Thames, at and near London, the suspension-bridge at Hammersmith interferes least with the navigation of the river, and is least exposed to injury from the action of the current upon its points of support; these having, to a certain extent, the effect of embankment-walls, which prevent the stream from spreading itself uselessly, if not injuriously, over a wide and shallow bed, and direct the current upon the mid-channel, whereby it is kept free and clear; whereas, the lumbering masses which support Putney Bridge obstruct the navigation, force the current into narrow rapids, which tend in every way to the destruction of the works themselves, and make the passage up the river dangerous. The laden barge of commerce and the double-banked barge of pleasure pass with or against the stream, and alike with ease and safety, under the tasteful and scientific erection, which carries a convenient and agreeable road over, and leaves the water-way uninterrupted; while both are exposed to inconvenience and danger where the ugly piles of Putney and Battersea support narrow and inconvenient roadways over the dammed-up river. In like manner, the effect of Southwark Bridge, with its two well-formed piers of neatly-executed masonry, is hardly felt upon the river; whilst the multitude of wry-looking angular piers of Vauxhall Bridge, standing across a bend of the river, are with difficulty avoided by the heavy craft, which depend almost entirely upon the current for motion. These are timber and iron bridges, of various forms and modes of arrangement; and with the materials of which they are composed, no sensible inconvenience, and much less obstruction, should in any case have been imposed upon the navigation of the river. That neither obstruction nor inconvenience is necessary with even a bridge of masonry is shown by the new London Bridge, which contrasts advantageously, not alone with its predecessor, but with all the other stone bridges upon the river, in these respects. The infrequency of the piers, and their moderate bulk, together with the expanse and elevation of the arches, preserving the head-way almost unabated over a great part of the whole width of the water-way, show in these, as in other respects, an example of the highest degree of perfection in the practice of bridge-building. . . . Had Labelye and Mylne built with granite, their works could not have been executed with the funds at their disposal, respectively; but with granite, and the means of applying it, they would possibly, or they ought to, have occupied less of the water-way with obstructions; and, with the means at their disposal of raising the approaches, they would probably have avoided making the roadways upon their bridges so steep as to be always inconvenient, and sometimes dangerous." (*Hosking.*)

The danger of contracting the water-way by piers is shown in the case of Hexham Bridge, over the Tyne, built by Smeaton. The piers were built upon a thin stratum of gravel which rested upon loose sand capable of yielding to the action of water, if once exposed to it. To prevent this exposure, the piers were furnished with rubble defences (Fig. 294), the effect of

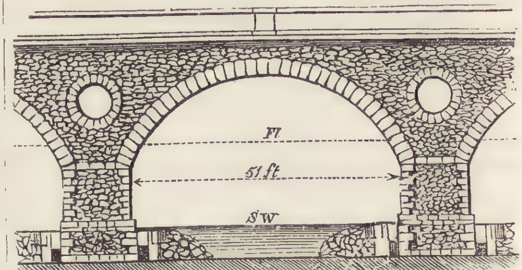


Fig. 294.

(1) Supplement to Mr. Weale's work on Bridges. Edited by George R. Burnell, C E. London. 1850.

which was further to diminish the already contracted waterway, and to raise the flood-waters to the head *Fl* requisite to scour it away, with the gravel under it, by which means the sand was exposed, and the piers at once undermined, so that the bridge fell. The river Tyne, in the part where the bridge stood, was about 530 or 540 feet wide, at the height of freshes or ordinary floods; this width the piers and abutment reduced one-fifth, leaving but 424 feet opening between the piers where they are thinnest, and the diminished width was further reduced below summer water-level by the greater substance of the piers at their footings, and by the defences of rubble packed around them, which had the effect of making an imperfect dam, or sunken weir, at every archway. "But the flood-waters had on previous occasions risen above bridge to the height of the springings of the arches without injury to the works, notwithstanding the pressure of a head of 3 feet of water, accumulated by the obstructions of the piers and their defences, and a scour arising from a velocity of from 800 to 900 feet per minute resulting from that head. Above the level of the springings, however, the arches themselves began to be immersed, and these in a rise of 3 feet in height above the springings, will have further diminished the water-way full 30 feet, when the pressure became sufficient to break up the crust of gravel that lay exposed between the toes of the rubble defences of the piers, to wash out the sand and loam from between the rubble, and to scour out a channel deep enough to compensate for the space that the piers of the bridge, with their defences, and the immersed haunches of the arches occupied." It is probable, in cases of this kind, if the bed of the river were deepened sufficiently to make the section of the water-way in the bays equal to the whole section of the bed or trough occupied by water before the erection of the piers, no danger would ensue. Under ordinary circumstances, the current will effect such deepening of itself; but while doing so, the piers are exposed to a great wearing action, which, in the case before us, proved fatal. Fig. 294 represents a longitudinal section of the central arch and its piers. The lower water-level is that of summer-water, and the top dotted line is the height above bridge of the flood which undermined and overthrew it.

Mr. Hosking remarks, that the substance in thickness of which bridge piers may be built, must depend in a great degree upon the materials of which they are composed, the height to which it may be necessary to carry them, and the weight of the arches, upper works, and load; it being taken for granted that the workmanship is good, as the thickest piers, badly wrought and built, may be unable to bear the weight they are intended to carry, though piers of half their substance might be sufficient. "If the piers of Westminster and Blackfriars bridges had been one-eighth or one-ninth the span of the arches resting upon them, instead of one-fourth and one-fifth of that proportion, as they are respectively, it is not improbable that both these bridges would have failed. The late operations for the repairs to their piers have exposed workmanship of the worst kind; even in the outside or ashlar courses, stone chips and pieces of slate and even deal chips were commonly found packed and wedged in to compensate for the leanness of the stones in both beds and joints."

Some of the piers of Old London Bridge were larger than the original openings of the arches; they consisted of small rubble stones laid in lime-mortar, surrounded by a thin casing of squared stones. The Roman bridges were probably constructed in the same manner. In modern bridges, the piers consist wholly of squared stones, each course being of equal height quite through the body of the pier. The thickness ought to be regulated by the span and rise of the arches, combined with the height of the piers. At the bridge of Neuilly the thickness is only one-ninth part of the span from the springing of the arches. The height is regulated according to circumstances, attention being given to the highest point to which the waters have ever been known to have risen.

With respect to the shape of the piers, the portion which supports the arch is usually oblong with right lined parallel sides. Under low-water the pier increases in breadth to the foundation. The rate of increase is regulated by the nature of the foundation, and the proportions which the body of the pier bears to the span of the arches. In many modern bridges this increase is at the rate of three inches for every foot in height. Large offsets are convenient for supporting the centres, but three or four inches in the stonework is sufficient for that purpose, the wooden platform projecting considerably more around the pier. The ends of the piers should be provided with salient angles to act as *cutwaters*. Some recommend that the shape of these cutwaters should be triangular, and that they should differ in the size; and others, where heavy craft are navigated, consider circular cutwaters best calculated to resist the effects of concussion. The form of a gothic pointed arch diminishing to its apex, seems best fitted for the division of the stream and for resisting the impulse of heavy bodies.

The shapes of the points of the piers are various, such as acute-angled, right-angled, semicircular, or two segments of a circle intersecting each other. Telford preferred the second and fourth of these forms. These projecting points are usually diminished from the limits of each side of the piers. Each course of stone around the outside should be laid header and stretcher alternately. The stretchers should be from eighteen inches to two feet in breadth, and the headers about one-third of the whole face, or each from three to four feet long. The upright, or end joints, should be correctly squared at least one foot in from the face, and in no part should be more than one inch in width. The interior, or filling-in stones, should be of equal height with the outside stones, and should have their upright joints not more than one inch wide: they should break joint at least one foot; the first and all succeeding courses should be laid flushed, with both their bed and upright joints in proper mortar. There should be an allowance for the thickness of the out-

side mortar joints of about one-eighth inch when compressed. All the joints should be run full of grout where there is any vacancy. The hardest and most perfect stones should be used for the projecting points of the piers, especially those on the upper side of the bridge. The points should be carried up at least to above high-water mark, and at that height to be usually finished by sloping them back to the face of the spandrels. The courses of stone may vary in thickness, eighteen inches being a good average.

The abutments are managed in the same manner as the piers, only their backing is generally made of good rubble stone laid in lime mortar. This rubble work must be levelled and grouted at the height of each course of square masonry, the whole to be properly bonded and connected together. If the bridge be wide, a buttress or counterfort should be placed behind the middle part of the abutment; it should be of rubble work well bonded into the body of the abutment, and having thin hoop-iron, laths, or half-inch boards laid in as they are carried up.

3. *The centres.* In the construction of an arch, a timber-framing called a *centre* or *center* (from the French verb *ceintre* or *cintre*), is necessary for supporting the voussoirs until they are keyed in. The centre must be strong enough to bear the weight or pressure of the voussoirs without any sensible change of form throughout the whole progress of the work, or fatal results may ensue, as in the case of a large arch erected over the river Derwent, on the line of the Glossop and Sheffield road. The men were proceeding to lay the keystone, when the centre gave way and fell with a tremendous crash into the river, causing the loss of several lives.

A centre should also admit of being easily and safely removed, and so designed that it may be erected at a moderate cost. In navigable rivers, where a certain space must be left for the passage of vessels, and in deep and rapid rivers, where it is difficult to establish intermediate supports, the frames should span the whole width of the archway. In other cases the framing may be constructed upon horizontal tie-beams, supported in several places by piles or frames fixed in the bed of the river.

Dr. Robison remarks that the general principles of carpentry furnish a rule for the construction of centres. To give the utmost possible strength to a frame of carpentry, every piece should be so disposed that it is subject to no strain but what either pushes or draws it in the direction of its length; and if we depend on timber alone for the strength of the centre, we must rest all on the first of these strains; for when the straining force tends to *draw* a beam out of its place, it must be held there by a mortice and tenon joint, which possesses but a trifling force, or by iron straps and bolts. Cases occur where it may be difficult to make every strain a thrust, and the best artists admit of ties; and indeed, where a tie-beam can be admitted connecting the two feet of the frame, no better security need be sought. But this may in some cases be inconvenient. In supporting the arch of a bridge, such a tie-beam would stop the passage of small craft up and down the river. It would often be in the water, and thus exposed to accidents by freshes, &c. Interrupted ties must therefore be employed, whose joint or meetings must be supported by something analogous to the king-posts of roofs. When this is judiciously done, the security is good. But great judgment is necessary in the disposition of the pieces. It is by no means an easy matter to decide whether a beam in a centre is in a state of compression or of extension. In some works we see pieces considered as struts and relied on as such, while they are certainly tie-beams, and should be secured accordingly. It is of great consequence not to be mistaken in this point; for in such case if the piece be stretched when we imagine it to be compressed, we are not only deprived of some support which was expected, but the expected support has become an additional load. To ascertain this point we may suppose the piers to yield a little to the pressure of the arch-stones on the centre frames. The feet therefore fly outwards and the shape is altered by the sinking of the crown. The frame must be drawn again for this new state of things, and we must notice what pieces must be made longer than before. All such pieces have been acting the part of tie-beams.

The centre has also to keep the arch in form: that is, while the load on the centre is continually increasing, as the masons lay on more courses of arch-stones, the frame must not yield and go out of shape, sinking under the weight on the haunches and rising in the crown, which is not yet carrying any load. The frame must not be supple; and must derive its stiffness not from the closeness and strength of its joints, which are quite insignificant when set in competition with such immense strains, but from struts or ties properly disposed, which prevent any of the angles from changing its amplitude. The strength and stiffness of the whole centre must be found in the triangles into which this frame of carpentry may be resolved. The strain which one piece produces on two others with which it meets in one point, depends on the angles of their intersection, and these are greater as an obtuse angle is more obtuse or an acute angle more acute. This suggests the general maxim, to avoid as much as possible all very obtuse angles. Acute angles which are not necessarily accompanied by obtuse ones, are not so hurtful; because the strain here can never exceed the straining force; whereas in the case of an obtuse angle it may surpass it in any degree.[1]

Centres are composed of separate vertical frames or trusses, placed from four to six feet apart, connected together by horizontal ties and stiffened by braces. When the frames have to span the whole width of the archway, the offsets of the stone-work afford a most substantial abutment for the support of the centre. There is generally one frame under each of the external rings of arch stones, and the intermediate space is equally divided by the intermediate frames. A bridge of three arches requires

(1) Robison, "System of Mechanical Philosophy;" edited by Brewster.

two centres; one of five arches three centres, and so on.

In the designing of centres, it is important to determine the point at which the arch-stones first begin to press upon the centre, and also the pressure upon it at different periods of the formation of the arch. It has been found by experiment that a stone placed upon an inclined plane does not begin to slide until that plane has an inclination of 30° from the horizontal, and until a stone begins to slide upon its joint, or bed, it does not of course press upon the centre. When a hard stone is laid with a bed of mortar, it will not slide until the angle becomes 34° or 36°. A soft stone bedded in mortar will stand when the angle which the joint makes with the horizon is 45°, if it absorb water quickly, because in that case the mortar becomes partially set. The pressure may in general be considered to commence at the joint which makes an angle of 32° with the horizon. This angle is called the *angle of repose*, and if we consider the pressure to be represented by the radius, the tangent of this angle will represent the friction: and considering the pressure as unity, the friction will be 0·625. The next course above the angle of repose will press upon the centre, but only in a small degree; and the pressure will increase with each succeeding course, so that when the plane of the joint becomes so much inclined that a vertical line passing through the centre of gravity of the arch-stone does not fall within the lower bed of the stone, the whole weight of the arch-stone may be considered as resting upon the centre. Mr. Tredgold [1] has given a method of estimating the weight upon a centre at any period of the construction, or when any portion of the arch-stones is laid, as well as when the whole weight which it has to sustain is laid upon it.

As the pressure increases very slowly until the joint begins to make a considerable angle with the horizon, the strength of the centre should be directed to the parts where the strain is greatest. For example, at the point where the joint makes an angle of 44° with the horizon, the arch-stone only exerts a pressure of one-fourth of its weight upon the centre; where the angle of the joint is 58°, the pressure exceeds half the weight; but near to the crown, the stones rest wholly upon the centre. Now it is of course unnecessary to make the centre equally strong at each of these points, and if this were done there would not be the means of applying strength where it is really required, without interfering with ties and braces, which are only an incumbrance to the framing. When the depth of the arch-stone is nearly double its thickness, the whole of its weight may be considered to rest upon the centre, when the joint makes an angle of about 60° with the horizon. If the length be less than twice the thickness, it may be considered to rest wholly upon the centre, when the angle is below 60°, and if the length exceed twice the thickness, the angle will be considerably above 60°, before the whole weight will press upon the centre. When the arch-stones are small, the pressure upon the centre is greater than when they are large.

In order to make a centre sufficiently strong to support any part or the whole of the pressure, the strains must not act very obliquely upon the supporting pieces, and the magnitude of the parts must be proportioned to the strain upon them. In order to support any part without a sensible change of form, the parts of the centre must be so disposed, that the stress may prevent any part from rising instead of causing it to rise; for there is this danger in large arches, when the arch-stones are laid to a considerable height, that they often force the centre out of form by causing it to rise at the crown, rendering it often necessary to load the centre at the crown to prevent such rising.

When arches are of small span the centres are easily managed, and when it is possible to obtain intermediate supports without great expense, large centres are not difficult. The centering of Conon Bridge, of which the span is 65 feet and the rise 21.8 feet, is a good example of this kind of construction: it was designed by Mr. Telford.

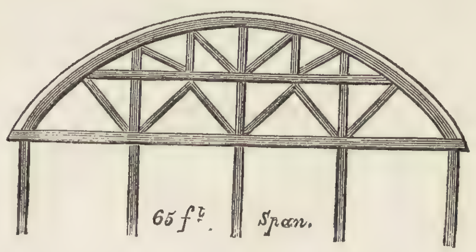


Fig. 295.

Fig. 296, is the centre designed by Smeaton for the Coldstream Bridge. The scantlings are contrived to suit the general scantlings of timber so as to save labour, and to have the timber in as useful a state as possible when it had served its purpose. "What I had in view," he says in his Reports, "was to distribute the supporters equally under the burden, preserving at the same time such a geometrical connexion throughout the whole, that if any one pile or row of piles should settle, the incumbent weight would be supported by the rest. With respect to the scantlings, I did not so much contrive how to do with the least quantity of timber, as how to cut it with the least waste; for as I took it for granted the centre would be constructed of east country fir, I have set down the scantlings, such as they usually are in whole balks or cut in two length-

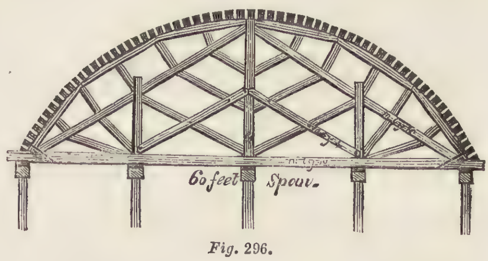


Fig. 296.

(1) Elementary Principles of Carpentry London, 1820.

wise." The arch which this centre carried was of stone, its chord 60 feet 8 inches, versed sine 18 feet, and width across the vertex 25 feet. The centering consisted of 5 frames or ribs.

Where intermediate supports cannot be obtained, centres require more care in the construction. The placing of a load upon the haunches must have a tendency to raise the centre at the crown, unless the frame be so contrived that it cannot rise there under the effect of any force that it may have to sustain at the haunches. In some of the centres constructed by the French engineers, there was a change of form with every course of stones that was laid upon them. Thus in the centre designed by Perronet, for the bridge of Neuilly, Fig. 297, it is obvious that such a centre loaded at A and B must rise at C, and the timbers being nearly parallel, the strains produced by a weight resting on any point must have been very great, and the consequent yielding at the joints considerable. "It is a kind of framing well enough adapted to support an equilibrated load, distributed over its whole length; but is one of the worst that can be adopted for a centre, or for supporting any variable load. It must have consumed an immense quantity of timber, and yet without the advantage of connexion. The quantity is crowded into so small

Fig. 297

a space that it has a light appearance, and consequently has obtained the approbation of those who are incapable of penetrating further than the apparent surface of things they pretend to examine. The centres for the bridges of Nojent, Cravant, St. Maxence, and Nemours, were designed on similar principles, and were found to be equally defective." Fig. 298 represents the centre of Waterloo Bridge, designed by Mr. Rennie. "In this centre by a

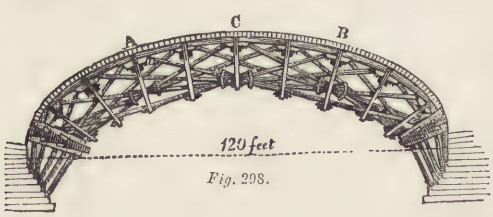


Fig. 298.

better disposition of its timbers, a load at A could not cause the centre to rise at C without reducing the length of the beam DE, and the one opposite it. There is an excess of strength in some of its parts, and it is complicated in the extreme; but on the whole it is a very judicious combination." Where timbers meet at an angle, it is desirable to let them abut into a socket of cast-iron, as was done in this case, Fig. 298. If possible the principal beams should abut end to end, and intersect one another as little as possible, as every joining causes some degree of settlement, and halving the timbers together destroys nearly half their strength.

Fig. 299, is a design for a centre by Mr. Tredgold. "Let the built beams EF, FF′, and F′E′ be each trussed and abut against each other at F and F′; then it is obvious that when the loads press equally at DD′, they will have no tendency to raise the beam FF′ in the middle, unless it be not sufficiently strong to resist the pressure in the direction of its length; and as it is easy to give it any degree of strength

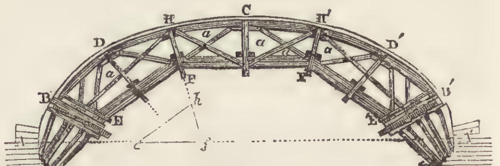


Fig. 299.

that may be required, a centre of this form may with a little variation in the trusses be applied with advantage to any span which will admit of a stone bridge. When timber is not to be had of sufficient length, the beams EF, FF′, and F′E′ may be built in the manner directed for building beams." These beams constitute the chief support; the arch is an ellipse, and consequently a considerable part of it will bear almost wholly on the centre. But if we take the whole weight of the ring between D and C and consider it to act in the direction HF at the joining F, it will be the greatest strain that can possibly occur at that point from the weight of the arch-stones. Produce the line HF to f and let hf represent the pressure; draw he parallel to the beam EF. Then as hf represents the pressure of the arch between D and C, he will be the pressure in the direction of the beam FE; and ef the pressure in the direction of the beam FF′: and these beams must be of such scantlings as will sustain these pressures. Let the weight of the arch from H to H′ be estimated, and if two-thirds of this weight be considered to act at C in a vertical direction, it will be the greatest load that is likely to be laid at that point, and the dimensions for the parts of the truss FCF′ must be found so as to sustain that pressure. The frame EDF may be calculated to resist half the pressure of the arch-stones between B and H. From D to C the whole weight of the arch-stones together with the weight of the centre itself may be considered as acting in a vertical direction at E, and the supports at GE should be sufficient to sustain the action of this pressure.

Perronet's general maxim of construction was to make the truss consist of several courses of separate trusses, independent as he supposed of each other, and thus to engage the joint support of them all. This centre consisted of a number of struts, set end to end, and forming a polygon. The trusses were so arranged that the angles of one were in the middle of the sides of the next, as when a polygon is inscribed in a circle, and another of the same number of sides is circumscribed by lines which touch the circle in the angles of the inscribed polygon. By

this construction the angles of the alternate trusses lie in lines pointing towards the centre of the curve. King posts were therefore placed in this direction between the adjoining beams of the trusses. These king posts consisted of two beams, one on each side of the truss, and embraced the truss beams between them, meeting in the middle of their thickness. The abutting beams were mortised half into each half of the post. The other beam, which formed the base of the triangle, passed through the post, and a strong bolt was driven through the joint and secured by a key or a nut. In this manner the whole was united, and it was expected that when the load was laid on the uppermost truss it would all butt together, forcing down the king posts, and therefore pressing them on the beams of all the inferior trusses, causing them also to abut on each other, and thus to bear a share of the load. This method of construction is the invention of Perrault. Its merits are fully discussed by Dr. Robison, in the first volume of his System of Mechanical Philosophy.

This construction, somewhat modified, was used by Perronet for the centering of the Bridge of Neuilly. The arch has 120 feet span and 30 feet rise, is 5 feet thick, and is remarkable for the flatness of its crown. The frames of the centering were 6 feet apart, and each carried an absolute load of 350 tons. The strut

Fig. 300 CENTERING OF THE PONT DE NEUILLY.

beams were 17 by 14 inches in scantling. The king posts were of 15 by 9 each half; and the horizontal bridles which bound the different frames together in five places were also 15 by 9 each half. There were 8 other horizontal binders of 9 inches square. As the stiffness of the framing depended on the transverse strength of the beams, care was taken not to weaken them by bolts. But notwithstanding this, the framing sunk upwards of 13 inches before the key-stones were laid; and during the progress of the work the crown rose and sunk by various steps as the loading was extended along it. When 20 courses were laid on each side, and about 16 tons laid on the crown of each frame, it sunk about an inch. When 46 courses were laid and the crown loaded with 50 tons, it sunk about half an inch more. It continued sinking as the work advanced, and when the key-stone was set it had sunk 13¼ inches. But this sinking was not general; on the contrary, the frame had risen greatly at the haunches, so as to open the upper part of the joints, many of which gaped an inch, and this opening of the joints gradually extended from the haunches towards the crown, in the neighbourhood of which they opened on the under side. This evidently arose from a want of stiffness in the frame. But these joints closed again when the centres were struck.

Dr. Robison remarks that the movements and twisting of this centre seem to indicate a deficiency not only of stiffness, but of abutment among the truss beams. The whole was too flexible because the angles were too obtuse. This arises from their multiplicity. Indeed, this centre should have consisted of fewer pieces, and their angles of meeting been proportionally more acute.

Dr. Robison gives by way of favourable contrast the details of Mr. Mylne's centre used for the arches of Blackfriars Bridge. The span of the arch is 100 feet and its height from the spring about 43. The leading maxim in this centre seems to be, that every part of the arch shall be supported by a simple truss of two legs resting one on each pier. The exterior joints are strengthened and the ring made as stiff as possible by apron pieces, from the ends of each of which proceed the two legs of the trusses. These legs are 12 inches square: they are not of an entire piece, but of several, meeting in firm abutment. Some of their meetings are secured by the double king posts, which grasp them firmly between them, and are held together by bolts. At other intersections the beams appear halved into each other; a practice which must weaken them and would endanger their breaking by cross strains, if it were possible for the frame to change its shape. But the great breadth of this frame is an effectual stop to any such change. No sinking or twisting was observed during the progress of the mason work. Three points in a straight line were marked on purpose for this observation, and were observed every day. The arch was more than 6 feet thick, and yet the sinking of the crown before setting the key-stones did not amount to one inch. This centre employs more timber than Perronet's, but is in every way stronger.

But with every care in the construction of centres there is always a sinking in the crown of the arch. Dr. Robison describes this in his peculiarly lucid manner. He says:—"By gradually withdrawing the centering, the joints close, the arch-stones begin to butt on each other and to force aside the lateral courses. This abutment gradually increasing, the pressure on the haunches of the centering is gradually diminished by the mutual abutment, and ceases entirely in that course which is the lowest that formerly pressed it: it then ceases in the course above, and then in the third, and so on. And in this manner not only the centering quits the arch gradually from the bottom to the top, by its own retiring from it, but the arch also quits the centering by changing its shape. If the centering were now pushed up again, it would touch the arch first at the crown; and it must

lift up that part gradually before it come again in contact with the haunches. It is evident therefore that an arch, built on a centre perfectly suited to equilibration, will not be in equilibrio when the centering is removed. It is therefore necessary to form the centering in such a manner, (by raising the crown,) that it shall leave the arch of a proper form. This is a very delicate task, requiring a previous knowledge of the ensuing change of form. But suppose this attained, there is another difficulty. While the work advances, the centering is warped by the load laid upon it, and continually increasing on each side. The first pressure on the centering forces down the haunches and raises the crown. The arch is therefore less curved at the haunches than is intended: the joints however accommodate themselves to this form, and are close and filled with mortar. When the masons approach the middle of the arch, the frame sinks there and rises up at the haunches. This opens all the joints in that place on the upper side. By the time that the key-stones are set, this warping has gone further; and the joints are open on the under side near the crown. It is true we are here speaking of an extreme case when the centering is very flexible, but this occurred to Perronet in the two great bridges of Neuilly and of Mantz. In this last one, the crown sunk above a foot before the key was set, and the joints at the haunches opened more than an inch *above*, while some nearer the crown opened nearly a quarter of an inch *below*. In this condition of things it is a delicate business to strike the centering. Were it removed in an instant, all would probably come down, for the arch-stones are not yet abutting on each other, and the joints in the middle are open below. "Perronet's method was to begin to detach the centering at the very bottom on each side equally, where the pressure on the centering is very slight. He cut away the blocks immediately under each arch-stone, and proceeded gradually upwards in this way, till all was detached that had been put out of shape by the bending of the centering. This being no longer supported, sunk inward till it was stopped by the abutment which it found on the arch-stones near the crown, which were still resting on their blocks. During part of this process, the open joints opened still more, owing to the removal of the load from the haunches of the centering. This allowed the crown to sink still more, by forcing out the arch-stones at the haunches. He now paused some days, and during this time the two haunches, now hanging in the air, gradually pressed in toward the centering, their outer joints closing in the meanwhile. The haunches were now pressing pretty hard on the arch-stones nearer the crown. He then proceeded more slowly, destroying the blocks and bridgings of those upper arch-stones. As soon as the support of one was destroyed, it immediately yielded to the pressure of the haunch; and if the joint between it and the adjoining one toward the crown happened to be open, whether on the upper or the under side, it immediately closed on it. But in this way it was found that every stone sank a little while it closed on its neighbour, tending to produce the deformity of a ragged soffit. They were therefore not allowed to sink so much. In the places of the blocks and bridgings which had been cut away, small billets were set standing on their ends between the centering and the arch-stones. These allowed the pendulous arch to push toward the crown without sensibly descending; for the billets were pushed out of the perpendicular, and some of them tumbled down. Proceeding in this way, he advanced to the very next course to the key-stone on each side, the joints closing all the way as he advanced. The detaching the three uppermost courses from the centering was most troublesome; for the whole elasticity of the centre was trying to unbend and pressing hard against them. They were found to be lifted up; for the joints beyond them, which had closed completely, now opened again below: but this was finished in one day, and the centre sprung up 2 or 3 inches, and the whole arch sunk about 6 inches. This was an anxious time," says Dr. Robison, "for he dreaded the great momentum of such a vast mass of matter: it was hard to say where it would stop. It stopped, however, very soon, settling slowly as the mortar was compressed, and, after one or two days, settling no more. This settling was very considerable, both in the bridge at Neuilly and in that at Mantz. In the former, the sinking during the work amounted to 13 inches. It sunk 6 inches more when the blocks and bridgings were taken out, and $1\frac{1}{2}$ when the small standards were destroyed, and $1\frac{1}{4}$ more next day; so that the whole sinking of the pendulous arch was $9\frac{1}{2}$ inches, besides what it had sunk by the bending and compression of the centering. In fact, the whole sinking of this arch was $23\frac{1}{2}$ inches. The sinking of the arches at Mantz amounted in all to $20\frac{1}{2}$ inches, of which 12 inches was owing to the compression and bending of the centering."

After the centres of the arches of the Pont de Neuilly had been eased in the manner described, the principal timbers were suddenly removed, in the presence of the king (Louis XV.), the court, and a vast assemblage of spectators, collected together, as Perronet modestly observes, in consequence of the presence of royalty. The whole formed a sort of *coup-de-spectacle* of a very striking kind. Perronet describes minutely the arrangements made for the occasion, and gives an animated view of the scene as it appeared on the 22d September, 1771. To render the manœuvre more interesting, it was arranged that all the frames of each arch should be made to fall in succession, within a few minutes. For this purpose, ropes were attached to the frames, and were drawn tight by capstans, placed at some distance on the land (see Fig. 301). Nine men were placed at each capstan, one of whom superintended the arrangement of the ropes, and another directed the motion of the capstan, each turn of which was regulated by the sound of drums. In this way the frames were all pulled down in $3\frac{1}{2}$ minutes. The fall of such a vast quantity of timber, which weighed at least 720 milliers for each arch, caused the water to rise in foam upon the bridge. The arches were thus com-

Fig. 301 STRIKING THE CENTRES OF THE ARCHES OF THE PONT DE NEUILLY

pletely exposed to view, and their light appearance and bold construction were generally admired. The string-courses, parapets, and masonry above were yet to be added. In this unfinished state of the bridge, it occasioned great surprise to see all this timber framing suddenly fall down, which, an instant before, seemed necessary to the support of the arches. The king, in returning to Marly, passed in a carriage over the new bridge. The spectacle came off without any accident, and a medal was struck to commemorate the occasion.

4. *The arches.* When the centres have been placed, and properly secured, the setting of the arch-stones is the next step. The masonry of the piers and abutments near the springing is properly adjusted, and, in some cases, immediately below the commencement of the curvature, it is usual to lay a capping, string, or cordon, the slight projection of which covers any small inaccuracy in setting out or carrying up the abutments and piers. The form and dimensions of the arch-stones are of the greatest importance. These have been greatly varied in different works. The French have used very deep arch-stones, which, in conjunction with their wide mortar-joints, has contributed to the great sinking of their arches. The depth of the arch-stones at the crown in the bridges of Orleans and Mantz is 6 feet. In Blackfriars and Westminster it is 5. Mr. Telford thinks from $2\frac{1}{2}$ to 4 feet a good length. "When they are longer, as the beds can scarcely ever be worked and set exactly true, they are apt to break when the weight comes upon them; and when shorter, there is not sufficient space to overlap or break the joints properly. Each course should be of equal thickness quite through between the headers. The thickness of each course should be from one-third to one-half their depth, and they should be chamfered or rusticated along the bed-joints, and also those of the outside heads. The beds should be worked as true as possible for the whole breadth of each stone; the neglect of which destroys every other precaution. Each stone should be laid so as just to swim in the mortar, and be struck with a maul two or three good blows. The joints of the headers should be of equal thickness with those of the other stones in the same course. Inexperienced masons, by laying the headers with thinner joints, for show of fine-work, frequently create an unequal pressure, which bursts or splinters the headers before the interior arch-stones come to an equal bearing." In setting the arch-stones, each course must point in the direction of the radius; and, that the workman may do this correctly, the thickness of each course should be marked upon the outer ribs, and its line of direction upon the lower part of the beams of the same ribs. The courses must also be carried equally on each side of the centre, and the masonry over the solid part of each pier in the spandrels must also be carried up. It is sometimes necessary to place a temporary weight upon the crown of the centre, until the load approaches the middle. This is done in Fig. 300. If the arches are flat, one side of the pier must not be exposed until it have sufficient weight upon it, or is guarded by resistance on the opposite side. At the bridge of Mantz, a neglect of this precaution caused one of the piers to be pushed $4\frac{1}{2}$ inches out of the perpendicular. By loading the opposite side, it was made to return $2\frac{1}{4}$ inches.

The keystones should be driven with moderate force, so as to fill their places firmly. When this is done, all the back and end joints of the whole arch should be carefully examined, and all vacancies run full of mortar, and firmly wedged with slates. The whole should then be left for some time to dry and get hard. Meanwhile, the masonry should be brought up in the spandrels to the level of about one-fourth of the rise of the arch. This was formerly, and is now, in some cases, of rubble-work. The outside stones in the part over the pier are carried up to the same height, but close to the arch-stones they are stepped or racked back, and so left until the centre is removed, because, if finished close up to the back of

the arch-stones, the least sinking of the arch would cause a fissure.

When the centres are removed, the soffit of the arch is carefully examined, and the joints pared, cleaned out, and pointed. The chamfered or rustic joints prevent the edges from chipping, and cover any trifling inequality, so that the cross joints only require paring.

5. *The spandrels and wing-walls.* The spandrels of a bridge are the spaces between the haunches of an arch and its vertex at the extrados of the roadway. When the arches are completed, the points of the piers are brought up and finished, at some distance above high-water mark, by sloping them back to the face of the spandrel, in a triangular or circular form, or otherwise disposing them to receive columns, pilasters, or turrets. The latter act as buttresses, as well as ornaments, and contribute to the stability of the superstructure. The spandrels are finished in various ways: in some of the old bridges they were filled up with earth or gravel. In small bridges, the masonry should be brought up to the level of about one-fourth of the rise of the arch, and then be sloped up to the top of the back of the arch-stones, and the remaining space filled up with gravel or stone rubbish. In large French bridges they have been filled up entirely with rubble masonry; but Mr. Telford objects to this as throwing unnecessary weight upon the arches. To remedy this, openings have been made quite through, as in Fig. 294, and kept open or concealed, or vaults have been constructed, to lighten the piers which sunk, or those adjacent to them. Fig. 302 shows the arrangement of the spandrels in

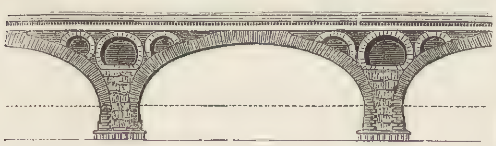


Fig. 302.

the Orleans Bridge, and Fig. 303 that in Blackfriars Bridge. But, as these arches are easily deranged by any settlement of the main arch, a better plan is to build walls longitudinally, 2 or 3 feet apart, and from

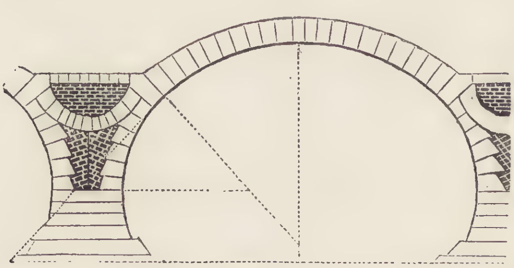


Fig. 303.

18 inches to 3 feet in thickness: founded upon the solid rubble masonry, and increasing in length as they advance in height, they rest upon and abut against the backs of each row of arch-stones, and act as struts between them. These walls are kept steady by laying long stones occasionally across from one wall to another. The outside spandrel walls, running parallel with these, and being connected with them by long stones, become a part of the general frame. These walls are carried up to near the level of the top of the arch-stones, where they are covered with two rows of flat stones, or the openings are arched over. Small openings are made in the walls upon the top of the rubble masonry, through which any water that may fall into the spandrels is conducted to one point, where it issues through a pipe inserted in the arch-stones.

The outside walls are usually made thicker than the interior: they are faced with square masonry, and have a rubble backing; the whole thickness being about one-fifth of its height. When these walls are very high, a wall is also built along the middle of the piers and abutments which cross each other, and into which they are tied by bond-stones or pieces of timber laid at about every six feet in height. When these spandrels have been brought up to the level of the top of the arch-stones, they are dressed into the slope which it is proposed to make the roadway. Here there is usually laid a cordon and cornice, extending along the whole of the arches, spandrels, and wing-walls. Its upper course should be of sufficient breadth to allow for the projection, and to pass quite through under the parapet, which, by standing upon it, will keep it secure. The upper side of the projecting part should have a slope or weathering, to throw off the water.

The wing-walls behind the abutments are sometimes laid at the same depth as the abutments, and are similarly secured by piles and platforms. If the ground be firm, they are founded by steps, rising up as they retreat. This saves much masonry. Their thickness is from about one-fourth to one-fifth their height. When very long and high, a cross-wall should be built, reaching between them, into which they should be tied. The wing-walls should terminate in newells or pilasters.

6. *The parapets* usually consist of a plinth, dado, and coping. They are made from $3\frac{1}{2}$ to 6 feet in height above the footpaths or roadway; but 4 feet 4 inches is sufficient for protection and decoration, and is not too high to obstruct the view. The dado, or middle member, is about 10 or 12 inches thick, but sometimes more; the plinth so much more than this as to leave an offset of about an inch on each side. The coping is usually made to slope each way from the middle. Balustrades are sometimes introduced instead of the dado; and in some cases, as where a bridge is exposed to violent gusts of wind, there are only half-balusters on the outside, the inside being solid.

7. *The roadway.* Gauthey remarks that most of the bridges erected before the eighteenth century were built with a view to economy, both with respect to the style of building and the degree of breadth allotted to them, since the most considerable scarcely allow room for two carriages to pass abreast. The bridges of Paris are for the most part very wide; but this extent was given to them solely with a view to erect two rows of small houses on their sides,—a circumstance which must naturally have produced a

very narrow thoroughfare. In modern bridges, the convenience for traffic is very properly the first consideration; a proper space being allowed for foot passengers, and another and larger space for horses and wheel-carriages.

When the spandrels have been covered by arches or flat stones, the foundations for the footpaths are built with rubble-stone for the outside curbing. This should be of hard stone, set in lime-mortar. The space between the curbing and the parapets should be paved with hard flag-stones, laid in lime-mortar upon a bed of coarse sand or clean gravel. The breadth of the footpaths may vary from 3 to 6 feet, or more. If the carriage-way is to be paved, there should be laid upon the covering of the spandrels and over the top of the arches a bed of gravel, mixed with loam, from 12 to 18 inches in thickness, worked with water into the consistence of mortar. When this has become moderately firm, squared paving-stones are set and well beaten, making a curve across the road of 6 inches in 24 in breadth, and that curve should be terminated by sinking 4 inches more in the distance of 2 feet from the inclined plane formed along the outer edge of the curbing-stones. But if the roadway be only of gravel, it must be laid 22 inches in depth in the middle, and 18 inches near the sides. The gravel should be mixed with a little loam, to consolidate it, and exclude water. A gutter of small squared stones should be formed on each side of the roadway, to carry off the water. This in all cases should be conducted beyond the extremity of the wing-walls, and got rid of in covered drains or sewers.

Respecting the decorations of a bridge, Mr. Telford sensibly remarks :—"The decorations should be varied according to the situation and accompaniments. In the country, the utmost simplicity consistent with distinguishing the essential parts, should be preserved; and even in the most splendid cities, or adjacent to palaces, all decorations should be kept perfectly subservient to, and in unison with, the essential parts. The neglect of this is a frequent error in designing bridges. Columns and entablatures, though proper in a Grecian temple, are ill suited to an edifice where forms unknown to the Greeks are the leading features. As columns can only be placed over the piers and abutments, the entablature, intended to represent beams of timber, cannot be supposed to be wholly upheld by supports placed at such great distances from each other. And the introduction of columns, in place of carrying up the piers, deprives the superstructure of powerful buttresses, in situations where they would prove very beneficial. The affectation of preserving the entablature upon a perfect level, has led to making the roadway along the bridge also level, which is nothing less than constructing, at a vast expense, a piece of road, more imperfect than what is formed by the common labourer in the open country; and besides, this mode of construction gives an appearance of feebleness to the outlines of a bridge." [1]

Nos. of reference to Figure 304.	Name and Situation of Bridge.	Number of Arches.	Clear Waterway.	Total Width, including Piers.	Width of Bridge between Parapets.	Form of the Centre Arch.	Dimensions of Centre Arch.					Material.	Date of completion.	Architect or Engineer
							Span.	Rise or Versine.	Radius of Curvature at the Crown.	Depth of the Keystone.	Thickness of the Piers.			
			Feet.	Feet.	Ft. In.		Feet.	Feet.	Feet.	Feet.	Feet.			
1	Vielle Bronde, over the Allier	1	183$\frac{1}{4}$	...	16 0	Circular...	183.25	70.25	94.87	5.25	...	Tufa	1454	Grenier and Estone.
2	Bridge of the Holy Trinity, over the Arno, at Florence	3	270$\frac{1}{2}$	322$\frac{1}{2}$	33 9	Slightly pointed	95.25	14.83	172.63	2.75	26	White marble..	1569	B. Ammanati
3	Pont-y-prydd, over the Taaf	1	140	...	...	Circular...	140	35	87.5	2.5	...	Sandstone	1755	Edwards.
4	Bridge of Mantes, over the Seine	3	358	409	35 5	False ellipse...	127.83	38.25	134.6	6.25	25.58	Saillancourt stone	1765	Perronet and Kupeau.
5	Blackfriars Bridge, over the Thames	9	780	926	42 0	Idem	100	41.5	56	6.58	20	Portland stone	1771	Mylne.
	Neuilly Bridge, over the Seine	5	639	766	48 0	Idem	127.83	31.83	260	5.25	13.83	Saillancourt stone	1774	Perronet.
6	Bridge of St. Maxence, over the Oise	3	230	249	41 6	Circular...	76.67	6.25	121	4.67	9.5	....	1784	Idem.
7	Waterloo Bridge, over the Thames	9	1,080	1,240	41 6	Ellipse....	120	32	112.5	5.0	20	Granite	1816	Rennie.
8	Gloucester Bridge, over the Severn	1	150	...	35 0	Idem	150	35	160	4.5	...	Sandstone	1827	Telford.
9	London Bridge, over the Thames	5	692	784	53 6	Idem	152	29.5	162	4.75	24	Granite	1831	Rennie.
10	Bridge over the Dee, at Chester	1	200	...	33 0	Circular...	200	42	140	4.0	...	Sandstone	1833	Hartley.
11	Bridge carrying the Great Western Railway across the Thames, at Maidenhead	2	256	284	28 0	Ellipse....	128	24.25	169	5.25	28	Bricks laid in cement	1835	Brunel.

The above Table, from Mr. Law's "Rudiments of Civil Engineering," contains the proportions and dimensions of some important bridges in Europe: it gives the radius of curvature of the main arch at its soffit, the depth of the keystones, and the materials of which they are composed. In these, as in most other examples, the form of the arch is either circular or elliptical; but the latter is now generally preferred, as the elliptical arch can be made of any height to the same span, or of any span to the same height, while, at the same time, its haunches are sufficiently elevated above the water, even when it is rather flat at the top,—a property

(1) From a valuable article on bridge-building, contributed to the Edinburgh Cyclopædia by Messrs. Telford and Nimmo, to which the writer of this notice is indebted for many useful suggestions.

which the other curves used for bridges do not possess in the same degree. This property is also the more valuable because, after the centre is struck, the arch settles more about the haunches than the other parts, by which the other curves are reduced near to a straight line at the top. Elliptical arches also look bolder, and are really stronger, although they require less materials and labour than the others.

The flattest stone arch of large size, of which the tangent of the curve at the springing is at right angles to the chord or span, is in the bridge of the Trinità at Florence. The span of the central arch is $95\frac{3}{4}$ feet, and the rise 15 feet $1\frac{1}{2}$ inch, or a little more than $\frac{2}{13}$ths of the span. It is built of marble; and no observable settlement has ever taken place in it, or in either of the other two arches, which carry the

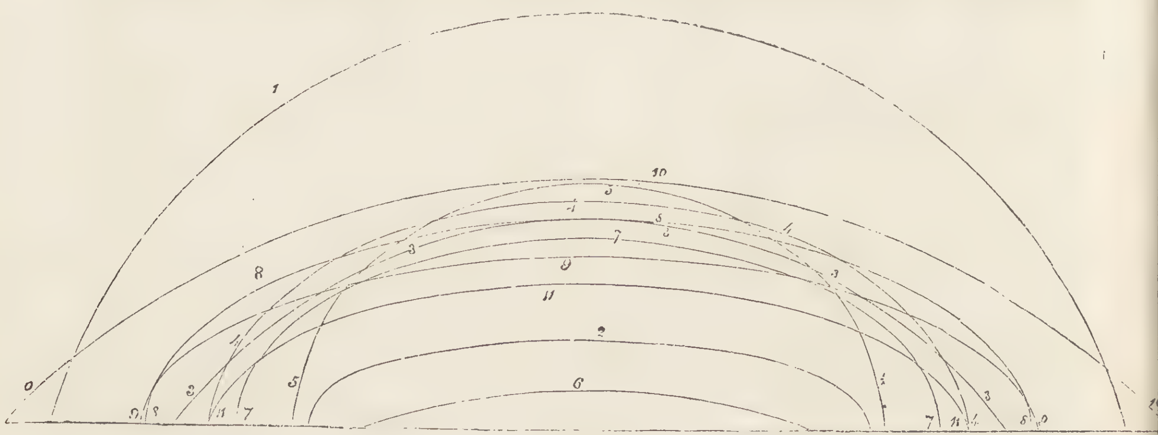


Fig. 304.

thrust up to the abutments. The flattest brick arches of large size are those of the bridge that carries the Great Western Railway over the Thames, at Maidenhead. These are semi-elliptical in form, and of 128 feet span, and $24\frac{1}{2}$ feet rise. The abutments are stepped on raking benches on the chalk stratum upon which they stand; and the resistance thus obtained appears to be sufficient. Mr. Law remarks, that, taking into consideration the materials of which it is composed, this bridge is certainly the boldest which has ever been constructed, the actual pressure at the crown of the arch being about one-third of that which would begin to injure the cohesive strength of the material of which it is composed. "And although the construction of this bridge has shown that it is practicable to approach much closer to the load which would cause failure than had before been considered safe, it is questionable how far prudence would warrant such an approach in ordinary cases; especially when we consider how many accidental circumstances may deteriorate the stability of the arch, to guard against which, it seems desirable that a much wider margin should usually be given, and that the greatest load upon the keystone should not be greater than $\frac{1}{20}$th of that which would *begin* to crush its material, in bridges exposed to only ordinary traffic; and in those which are continually exposed to the tremour and vibration occasioned by a continuous and very heavy traffic, not more that $\frac{1}{30}$th."

Section IV.—On Timber Bridges.

The oldest wooden bridge on record is the bridge of Sublicius, which existed at Rome 500 years B.C. It is celebrated for the combat of Horatius Cocles, a Roman knight, who saved the city by his noble defence of this bridge. It is stated to have been put together without iron or nails. A wooden bridge was erected by Julius Cæsar for the passage of his army across the Rhine. The passage was effected ten days after they began to carry the timber for its erection. The bridge built by Trajan over the Danube appears to have been of timber, except the piers, which were of stone. The roadway seems to have been supported by three concentric curved ribs of timber, connected by radial pieces. There were 20 or 22 stone piers, and each wooden arch was above 100 feet span.

In the middle ages, when men began to establish bridges on the passages over the principal rivers, it was customary to erect piers 15 to 20 feet apart, consisting of one or more rows of piles. They were defended by a kind of jetty to break the ice, which also served to protect them from the shock of bodies borne down by the current; frequent repairs were, however, required, and the accumulation of matters against the piles blocked up the water-way, and the bridge became incapable of resisting the pressure of water in the time of high floods. In these early times of modern bridge-building, abundance of material was used, without much skill in its arrangement; but in places not subject to floods, and in situations where the piers could be kept light, more elegant structures were erected. A bridge built by Palladio over the Brenta, near Bassano, is a good example of this kind of bridge. This great architect has given several designs for bridges, which have been adopted in later times. He appears to have been the first among the moderns who attempted that species of construction which renders numerous piers unnecessary, thereby avoiding the shock to the timber-work of bodies carried down by the current. His bridge over the torrent of Cismone, near Bassano,

Fig. 305, was of this kind, with a span of 108 feet.

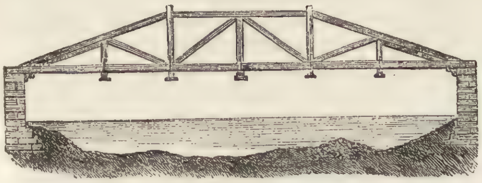


Fig. 305.

Another of his designs, Fig. 306, is a system of what

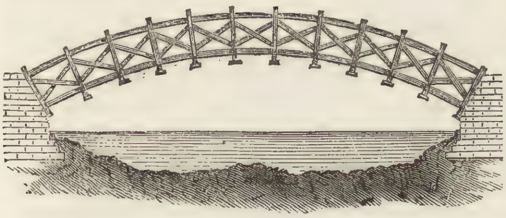


Fig. 306.

may be termed *framed voussoirs*, similar to the arch-stones of a stone bridge,—a principle that has since been successfully adopted, both in timber and in iron bridges.

One of the best modern methods of construction is that of forming curved ribs for the support of the roadway. This method, introduced by Mr. Price, is thus described by Tredgold. "He proposes the curved rib to rise about one-sixth of the opening, and to divide it into a convenient number of equal parts, according to the span, or to suit the lengths of the timber. For a bridge of 36 feet span, he proposes to make the ribs of oak, in five lengths, and 3 inches in thickness; each rib to consist of two thicknesses, one 12 inches deep, and the other 9 inches deep; the joints crossed, and the thicknesses keyed together with wooden keys. Two of these ribs, with joists framed between, he says, will be sufficient for the roadway." This method of construction, which has been brought to considerable perfection in Germany, America, and other places, will be understood from Fig. 307, in which D E F are three beams of the arch, consisting of logs of timber of small lengths, such as 10 or 12 feet, or such as can be found of a curvature suited to its place in the arch, without trimming it across the grain. Each beam is double, consisting of two logs, applied to

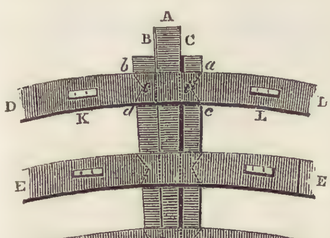


Fig. 307.

each other side by side, *breaking joint*, as the workmen term it. They are kept together by wedges and keys, driven through them at short intervals, as at K, L, &c. The manner of joining and strongly binding the two side-pieces of each beam is as follows:—the mortise *a i c b* and *d c i o*, which is cut into each half-beam, is considerably larger on the outside than on the in, where the two mortises meet. Two keys, B B C C, are formed, each with a notch, *b c d* and *a i o*, on its side, which notch fits one end of the mortise. The inner side of the key is straight, but so formed that when both keys are in their places they have a space between them wider at one end than at the other. A wedge, A A, having the same taper as this space, is put in and driven hard, thus holding the two logs firmly together.

Colonel Douglass, in his work on "Military Bridges," notices the wooden arch, of 250 feet span, across the Portsmouth River, in North America. It was put together with wooden keys, on Price's method of construction, applied to a larger span, except that there is some difference in the form of the keys. The Colonel observes, that the arch is extremely flexible, and that diagonal braces would be an improvement in it. Also that if the three ribs had been placed close above one another, and firmly connected together, the bridge would have been much better adapted to resist any unequal load, because, in such case, they would have formed a solid beam, equal in depth to the sum of their depths. Tredgold remarks that it would have been still better to have made the same quantity of timber into two ribs, with cross ties and diagonal braces between them; that the method of connecting the parts by means of dovetail keys is objectionable, as the timber must be greatly weakened by such large mortises, and a very slight degree of shrinkage renders them useless; that it is still more objectionable as applied to the radial pieces, which would have been much better notched on in pairs, and bolted through.

There are many excellent wooden bridges in Switzerland. One of the most celebrated was that at Schaffhausen, constructed in 1757 by John Ulrich Grubenmann, a village carpenter of Tuffen in Appenzel. It was composed of two arches, one 172 feet, the other 193 feet span, supported by abutments at the ends and by a stone pier in the middle, which remained when the stone bridge was swept away in 1754. In this bridge the oak beams which rested upon the masonry of the abutments and pier not having been properly seasoned, nor raised from the stone-work so as to allow the air to circulate around them, they rotted, and the frames began to settle. Grubenmann being dead, a carpenter of Schaffhausen named Spengler, undertook in 1783 to supply a remedy. He raised the whole bridge by means of screw-jacks upon scaffolding supported by piles, and replaced the decayed timbers by others of better quality. This was the only repair required by the bridge during the 42 years of its existence. It was burnt by the French army in 1799. The principle of its construction is shown in Fig. 311. Its chief defect was that all the principal supports were so dependent upon one another that a single part could not be removed without first supporting the whole bridge. This bridge in common with others constructed on the same principle bent considerably sideways.

Mr. Coxe says, that a man of the slightest weight felt this bridge almost tremble under him; yet waggons heavily laden passed over it without danger. It is frequently stated that the middle pier was not necessary as a support: the bridge however could not have borne its own weight without such assistance.

The general principles upon which timber bridges are constructed are very simple, and belong rather to Carpentry than to bridges. It will, however, be desirable to introduce a short notice of them here. If AB, Fig. 308, be a solid beam resting upon the supports A and B so as to form a roadway, it will

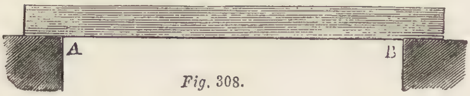


Fig. 308.

have to support not only its own weight, but the planking and roadway and any heavy body moving over it. Now in order to strengthen such a beam without using a larger quantity of timber, we have only to make it deeper in the middle and thinner at the ends, as in Fig. 309, for a strain at C will have

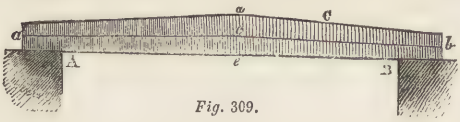


Fig. 309.

less effect in bending the beam than a similar strain in the middle. But if the weight be sufficient it will cause the beam to bend however it may be distributed, in which case the fibres at the upper side *d* will be compressed, and those on the lower side *e* extended. A line may however be drawn at the middle of the depth *acb*, where the fibres remain in their natural state, being neither extended nor compressed. But all the fibres between *c* and *d* are compressed, and all those between *c* and *e* are stretched; but not equally so, because the nearer a fibre is to the points *d* or *e* the more it is strained. Now as the middle part of the beam is very little strained compared with the upper and lower side, it is obvious that the same quantity of timber can be employed more effectually by using a deeper beam and cutting out the middle, as in Fig. 310. On examining the forces exerted by the parts of the beam

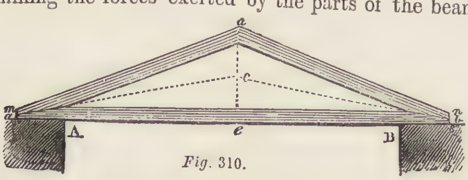


Fig. 310.

it will be seen that the upper part *amdnb* is wholly compressed in the direction of its length, and that the lower part *aresb* is wholly extended in the direction of its length; and as timber offers the greatest resistance when strained in this direction, provided the joints are made secure, we are thus led to the kind of construction shown in Fig. 311, where the same pressures are evidently obtained as in the perforated beam, Fig. 310, the only difference being that in this case it is necessary to support the tie beam, or it would fail in large spans. The celebrated bridges of Schaffhausen, Zurich, Landsberg, and Wettingen, are constructed on this principle. In the bridge of Schaffhausen the timbers are disposed nearly as in Fig. 311; the continued tie AB retaining

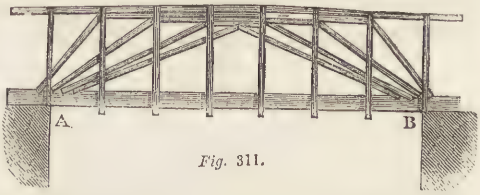


Fig. 311.

and being an abutment for the compressed beams: the frame requires only to be supported, and has no other thrust on the abutments of the bridge than a solid beam would have. Framed bridges such as that designed by Palladio, Fig. 306, may be referred to the same principle.

Advancing a step further it is easy to construct a bridge in which the tie is entirely removed, but in such cases the abutments must be capable of sustaining the thrust. Hence we get the kind of construction shown in Fig. 312. But as long pieces of

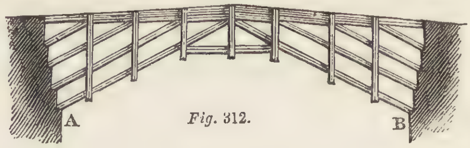


Fig. 312.

timber require to be of a proportionate depth and breadth and cannot be easily procured, and as much of their strength is lost in scarfing, it is desirable to construct with short timbers. Hence we get such a combination as is shown in Fig. 313, which is a

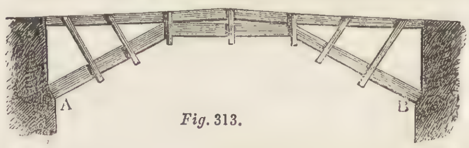


Fig. 313.

very common form. It was adopted by Palladio in a bridge across the Brenta. By dividing the span into shorter lengths than is here shown, little or no advantage is gained, because the angles of junction become more obtuse or open, and the strain in the direction of the pieces is much increased. Although such a bridge might bear a constant load, a load moving over it would soon derange it, because the strength of such a system to resist a variable load must depend wholly on the strength of the joinings, which cannot be made very strong. Bridges on this

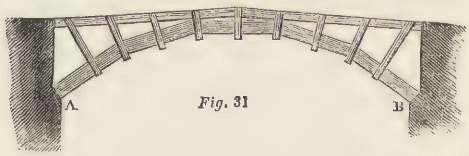


Fig. 31

principle have, however, often been executed, as in Fig. 314, which shows the method adopted for the

arches of the bridge over the Thames at Kingston: the span is 49 feet. Combinations of this kind naturally lead to the continued curved rib, which possesses advantages not found in a series of beams merely abutting end to end; for when the rib is built of short lengths with the joints crossed and the different thicknesses firmly bolted together, it becomes as one solid beam. If the straining force be applied at D, Fig. 315, it must be sufficient to fracture the

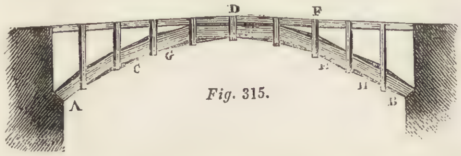


Fig. 315.

rib at C, D and E; therefore when the strength of the rib is capable of sustaining the strains at C, D and E, and the curve is a proper curve of equilibrium to the constant load, this combination is both secure and simple. The use of curved ribs of this kind was known at a very early period, and it has been further improved by bending the pieces that form the ribs. Many considerable structures on this principle have been erected, among which may be mentioned the bridge near Bamberg over the Regnitz, designed by Wiebeking, and built in 1809. Cast-iron bridges are constructed on nearly the same principle, as in Southwark Bridge, designed by Mr. Rennie, consisting of three arches, the span of the centre arch being 236 feet.

As a bridge with a curved rib and of considerable pan yields at D, C and E, Fig. 315, when the load is applied at the middle, the strength must be increased by increasing the depth of the rib. This leads to the construction of a framed rib, Fig. 316. But in

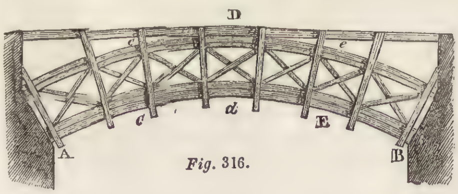


Fig. 316.

such case the two curved ribs must be continuous, and put together so as to resist either extension or compression: for when a load is placed at D, the lower rib will be extended to *d* and compressed at C and E; while the upper one will be compressed at D and extended at *c* and *e*; a weight applied at any other point would produce a similar effect. In bridges of large span framed ribs greatly add to stability. The framed voussoirs by Palladio, Fig. 306, resemble this kind of construction, but they are better adapted for iron bridges, where the parts cannot be very firmly united, in consequence of the expansion and contraction of the material according to variations in temperature; but in timber, where nothing is to be feared from this cause, it is, as Tredgold well remarks, losing one of the greatest advantages of the material to interrupt the connexion of the parts: besides, many joints should be avoided, on account of the difficulty of making them fit so as to bring every part alike into action, and also of the difficulty of preventing decay at the joinings.

In cases where it is difficult to form abutments and it is desirable to keep the roadway as low as possible, Tredgold recommends such a construction

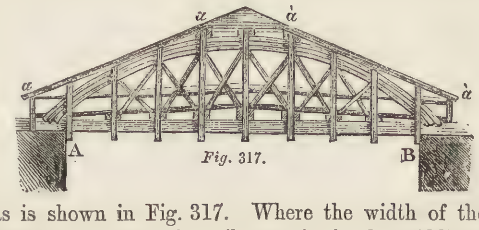


Fig. 317.

as is shown in Fig. 317. Where the width of the bridge is considerable a rib may rise in the middle of the width so as to divide the roadway into two parts, or a double rib with a footway between. As cross ties will be required at the top, the middle parts may be covered with a roof to protect them. A continued coping *a a a' a'* might be put over each truss, which would improve the appearance and protect the framing.

By the application of some of the simple combinations thus noticed, the carpenter will be able to span any opening of moderate dimensions.

Wiebeking states that a rise of 1 in 24 is a convenient ascent for a bridge; that in timber bridges the settlement is generally about 1 part in 72; that is, if a timber bridge of 144 feet span rise one foot in the middle when first framed, it will settle so as to become nearly horizontal; so that when it is intended for the bridge to have an ascent of 1 in 24 when finished, it must be framed so as to have a rise of 1 in 18; for $\frac{1}{18} = \frac{1}{24} + \frac{1}{72}$.

Section V.—Suspension Bridges.

A suspension bridge derives its chief value from the fact that it is independent of the bed of the river which it crosses. Hence it can be thrown across an opening where it is impossible, either from the rapidity of the current or from the altitude of the banks, to erect centering for a stone bridge. It can also be built with ease and expedition; and as it requires only a small amount of materials, it is economical. There is also an elegant lightness about a suspension bridge; it is however on this account much slighter than stone or iron bridges, and there is probably no suspension bridge that would bear permanently the load that is passing every hour over London Bridge. "A bridge destined to be a great and perpetual thoroughfare, exposed not only to be frequently quite filled with people, and to the passage of troops, but also to the rapid motion of great numbers of heavy vehicles; in short, a bridge in a busy part of a great city, ought not to be on the suspension principle. For if it were made no stronger than our strongest suspension bridges, it would not possess sufficient stability. If on the other hand the strength were increased to a sufficient extent to enable it to bear safely its constant work, the weight, the difficulty of getting up the chains, and the increase in the masonry part, would so raise the expense, that it is doubtful how far it

could be brought under that of a stone or cast-iron bridge. Add to which, a suspension bridge would never equal in stability a common arch bridge, because it is subject to vibrations, the law of which is not sufficiently known to calculate their precise results in practice, but which certainly are more dangerous in a heavy bridge than in a light one. The object therefore in building a suspension bridge, is either to make it so light that its own vibration shall not hurt it; or if, as in nine cases out of ten, that cannot be done, then to make it so heavy and stiff, in proportion to the load it will have to carry, that the load shall not cause it to vibrate much. This, for a bridge liable to be constantly loaded with as much as it could contain, would be impracticable."[1] For large openings where the traffic is small, suspension bridges are well adapted, because they can be carried to almost any span and any height, for a comparatively moderate expense. They are also well fitted for military bridges; the chains, or cables, the platform and even timbers being ready prepared to frame suspension piers, might be carried more conveniently than a pontoon bridge, and could be rigged up for use in a short time. They are also well adapted for crossing chasms in mountainous countries; and on a great military pass, a bridge of this kind would give the inhabitants greater command over it: for by knocking out a few connecting bolts, a whole bridge might be dismantled very rapidly without being destroyed. For piers or jetties on the sea-coast they are well adapted, from the openness of their construction. "If the suspension towers are founded on piles, and themselves made of strong but open framework, and if the chains and platform are properly combined to get as much stiffness with as little weight as possible, so that they may resist vibration, without being so heavy as to be endangered by the vibration they cannot resist, a suspension pier may be buried in the waves without being hurt."

The bridges of ropes, &c. mentioned at the beginning of this article, are true suspension bridges in their rudest form. They are very numerous in various parts of the world. In China, where the germ of nearly every thing connected with the Useful Arts is found, suspension bridges are formed of five parallel chains with links one foot in diameter, on which a loose bamboo flooring is laid. Another form is described as consisting of two parallel chains 4 feet apart, suspended over stone piers about 8 feet high on each bank. The ends of the chains pass back from thence, turn obliquely, and are bedded in the rock, each being fastened round a large stone, which is kept down by a mass of smaller stones laid upon it. A plank about 8 inches wide, extending across the river, is suspended from the chains by bands made of roots, of such length that the path is 4 feet below the chains in the middle of the length of the bridge. The suspending bands are renewed every year, and the planks are loose, so that any part can be repaired separately. The length of one of these bridges is described as being 59 feet. It is only used for foot-passengers; but it is a proper suspension bridge, with a horizontal platform suspended from the main chains.

Bridges of rope or cordage are described in works on Military Engineering as early as the year 1631, and perhaps earlier, but there does not seem to be any account of the existence of iron suspension bridges in Europe before the middle of the last century. About the year 1741, the first European chain-bridge was built in England across the Tees, two miles above Middleton, chiefly for the use of the miners of that district. The length was 70 feet, the breadth rather more than 2 feet, and the height above the water 60 feet. It appears to have been a very rude work, not superior to the Chinese chain-bridges. It attracted no attention at the time, nor does the construction of suspension bridges appear to have occupied the attention of English engineers until 1814. In America however iron suspension bridges were erected as early as 1796, by Mr. Finlay, who, in 1801, took out a patent for their construction. In 1811, eight bridges had been built on Finlay's plan.

In 1814, a plan was advanced by Mr. Dumbell of Warrington, for making a direct road from Runcorn in Cheshire, across the Mersey to Liverpool. The scheme included a bridge instead of a ferry across Runcorn-gap, and it was suggested to stretch across the river a web of metallic rings. From the nature of the navigation, it was necessary that any bridge to be constructed should consist of not more than three openings, the centre one of 1,000 feet, and the other two of 500 feet each, with a height of at least 70 feet under the bridge above high water. These conditions being submitted to Telford, he proposed an iron suspension bridge to consist of 16 iron cables, each formed of 36 square half-inch iron bars, and of the segments of cylinders proper for forming them into one immense cylindrical iron cable, which was to be nearly half a mile long, including the fixings on shore, and about $4\frac{1}{4}$ inches diameter. The half-inch bars as well as the four segments were to be welded together into so many lines of bars, and laid in a bundle together, secured by bucklings every 5 feet, and wrapped in flannel saturated with a composition of rosin and beeswax, to preserve them from the weather. They were further to be bound together with wire of about $\frac{1}{10}$th inch diameter. The roadways were to be suspended from 16 of these cables, and to consist of two carriage ways and one central footpath. The main suspension piers of the middle opening were to be about 140 feet high, and the deflection of the cables in the middle $\frac{1}{20}$th of the opening or 50 feet.

At the time this bridge was proposed, there was but little experience on the construction of suspension bridges; and in order to obtain data for proportioning the strength of the parts, Telford undertook a course of experiments in 1814 upon the tenacity of malleable iron. "The inquiry was commenced by proving what force would tear asunder lengthways pieces of iron from $1\frac{1}{2}$ inch to $\frac{1}{20}$ inch in diameter. The experiments upon the first or larger diameters were performed with great accuracy, with an excellent hydrostatic machine, constructed by Mr. Fuller, at Mr. Brunton's

(1) "A Memoir on Suspension Bridges," &c. by Charles Stewart Drewry. London, 1832.

patent chain-cable manufactory, Commercial Road, London; those upon the smaller diameters were made by weights attached perpendicularly, and sundry times repeated. Having ascertained their powers when suspended perpendicularly, I next made experiments upon different diameters from $\frac{1}{10}$ to $\frac{1}{20}$ of an inch, drawn horizontally and with different degrees of curvature: all these were done between points 900, 225, 140, 131½ feet apart, and repeated sundry times upon the different distances and diameters. The number of experiments in all amounts to above 200.

"In the experiments made upon $\frac{1}{10}$ inch and under, the wire was drawn over pulleys; sometimes both ends were fixed, and sometimes one end only, the other having weights attached perpendicularly, to show their effects when compared with those loaded upon the curved part of the wire: these last were disposed at the ¼, ½, and ¾ divisions of the distance over which it was stretched. Having completed these experiments, I next proved what force by a blow would break the wire when stretched nearly horizontal, and at different curvatures, which was done by dropping weights from a given height. The several wires upon which these experiments were made were weighed, and the weight of 100 feet in length of each noted.

"The results of these experiments were, that a bar of good malleable charcoal iron one inch square, will suspend 27 tons, and that an iron wire $\frac{1}{10}$ inch diameter, (100 feet in length, weighing 3 lbs. 3 oz.) will suspend 700 lbs.; and that the latter with a curvature or versed sine of $\frac{1}{50}$th part of the chord line, will support $\frac{1}{10}$th part of the weight suspended perpendicularly, when disposed equally at ¼, ½, and ¾ of its length; and with a curvature of $\frac{1}{20}$th of the chord, it will bear ⅓d of the aforesaid perpendicular weight, disposed in a similar way. Experiments upon the other diameters correspond sufficiently, and it was found that increasing the distance only varied the effect by the difference of the weight of metal contained in the wire employed.

"A wire $\frac{1}{10}$ inch in diameter, drawn very tignt between points 32½ feet apart, resisted the impulse of a 20 pound weight falling from a height of 7¾ feet. Several other experiments were tried with lesser weights upon this and smaller wires.

"From these experiments I had reason to be satis fied that English iron made with wood charcoal, had sufficient tenacity to bear itself, and a portion to spare equal to the purposes of a bridge across an opening of 1,000 feet, and therefore considered myself justified in proceeding to form designs."

The project for the Runcorn bridge was not carried out on account of the great expense of the undertaking; but it served to direct the attention of engineers to the subject, and may thus be regarded as the origin of the great extension that has since been given to the suspension mode of bridge-building. Between the time here referred to, and the erection of the Menai Suspension Bridge, several small suspension bridges had been erected in Great Britain. The first was built in 1816, by Mr. Lees at Galashiel, across Gala Water, to establish a communication between different parts of his manufactory. It was made of slender wires: the span was 111 feet, and the cost about 40*l*. Another bridge of iron wires was built in 1817 across the Tweed at King's Meadows. It is 110 feet long, and 4 feet wide. It was constructed by Messrs. Redpath and Brown, of Edinburgh, and cost about 160*l*. It is supported by two hollow cast-iron columns 9 feet high, 8 inches diameter, and ¾ inch thick in the metal, set on the opposite banks of the river 4 feet apart: in each column is placed a wrought-iron bar 10 feet high, 2½ inches square; and the suspending wires are attached each separately to these bars by screw-bolts 1 inch diameter. The lower ends of the cast-iron columns stand on a framed wood foundation. The roadway is formed of wrought-iron frames, to which deal planks 1½ inch thick are bolted. The side railing is of wrought-iron rods: the suspending wires are about $\frac{3}{10}$ths of an inch diameter, and are not arranged in a catenary, but one end of each is fastened to its supporting bar, and the other end is fastened to a part of the roadway, so that the wires are a set of inclined lines forming different angles with the vertical supporting bars, Fig. 318. When the wires are

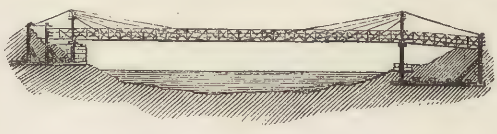


Fig. 318.

drawn tight by the screw-bolts the roadway is said to have very little motion. The strength of this bridge was tried shortly after its erection, by filling it entirely with a crowd of people, and it received no injury.

The system of inclined wires was adopted in a bridge built in 1817, at Dryburgh Abbey, across the Tweed, by Messrs. Smith. It was 260 feet span, and 4 feet wide. It was observed that the bridge had a very sensible vibration when crossed by any person, and the motion of the chains appeared to be easily accelerated. In 1818, six months after the completion of the bridge, a violent gale of wind caused so great a vibration of the chains that the longest chains broke, the platform was carried away, and the whole bridge destroyed. The vertical motion of the roadway was said to be, just before breaking, as great as the horizontal motion, and sufficiently violent to have thrown a person off the bridge.

"The defect of this plan of supporting a suspended roadway by inclined chains, fastened at the ends to the platform, is, that the chains, being of different lengths and inclinations, form different curves, and are exposed to very different degrees of tension; the long ones being the most strained, and the shortest the least. In a bridge of large span, and made with chains of any considerable weight, it would be almost impracticable to strain the inclined chains (especially the long ones) quite, or even nearly, tight; for if

that were done, the tension to which they would be exposed would so far absorb their strength as to leave them little power of carrying any load beyond their own weight. On the other hand, by leaving them slack enough not to impair their strength, the difference of curvature and tension of the several chains, and their want of connexion and uniformity of action, cause the vibration to which they are exposed, from gusts of wind or the motion of carriages, to act unequally on the several chains; and the vibration is likely to be violent in proportion to the slackness of the chains. These reasons have probably led to the abandonment of this system for large suspension bridges. . . . In suspension bridges of large dimensions, and consequently of great weight, the force that the suspended mass will acquire by being put in motion increases rapidly. Hence, it is an object to make it resist motion, and especially to make every part bear its fair share of strain. It is a common doctrine that lightness is the peculiar excellence of a suspension bridge; but that is a principle which must be acted upon with discretion, and not taken generally; for a bridge may be from its size just so heavy that, by being put in motion, it will acquire great momentum, and just so light and slight that it will be unable to resist the effects of its own vibration. Therefore, when it becomes necessary to make the chains of a bridge so heavy that vibration would be dangerous, it is advisable boldly to increase their weight, rather than attempt to diminish it, and to bind and connect the several chains and the roadway firmly together, in order that there may be sufficient mass and stiffness in the bridge to resist motion, rather than yield to it readily."—*Drewry.*

Mr. Robert Stevenson, in a paper on suspension bridges, inserted in the 5th Vol. of Jameson's Edinburgh New Philosophical Journal, says:—"The effect we have to provide against in bridges of suspension is not merely what is technically termed *dead weight.* A more powerful agent exists in the sudden impulses or jerking motion of the load, which we have partly noticed in the description of the Dryburgh bridge. The greatest trial, for example, which the timber bridge at Montrose, about 500 feet in extent, has been considered to withstand is the passing of a regiment of foot, marching in regular time. A troop of cavalry, on the contrary, does not produce corresponding effects, owing to the irregular step of the horses. The same observations apply to a crowd of persons walking promiscuously, or a drove of cattle, which counteract the undulating and rocking motion observed on some occasions at the bridge of Montrose, when infantry has been passing along it. Hence, also, the effects of gusts of wind, often and violently repeated, which destroy the equilibrium of the parts of a bridge of suspension; and the importance of having the whole roadway and side-rails framed in the strongest possible manner."

The destruction of the Dryburgh bridge created a great sensation of regret throughout all parts of the country. Its utility when compared with a troublesome ferry, even in the short experience of six months, had given it such a decided preference to the boat, that the Earl of Buchan, the owner, ordered it to be restored. This was accordingly done, after a better design, for the additional sum of 220*l.*, (somewhat less than 500*l.* having been paid for the original structure, which the contractors agreed to uphold against all accidents only during the period of its erection,) and, in less than three months, it was again opened to the public. The bridge was reconstructed on the catenarian principle, the roadway being suspended by perpendicular rods of iron from main or catenarian chains. The chief mechanical alterations upon the former plan consisted in welding both eyes or ends of the links, instead of having one of them simply turned round, and fixed with a collar. The roadway was also strengthened by a strongly trussed wooden rail, which also answers the purpose of a parapet, on each side of the bridge, the good effects of which were particularly exemplified while the bridge was building. A high wind having occurred before the side-rails were erected, one end of the platform was lifted above the level of the roadway, and the undulating motion produced on this occasion is described as resembling a wave of the sea; an effect which pervaded the whole extent of the bridge, and went off with a jerking motion at the further end. But after the side-rails were attached, this vertical motion was checked, and afterwards greatly reduced. There were also added gyes or mooring-chains, consisting of rods of iron fixed to stakes in the opposite banks of the river, and attached to the beams of the roadway. These diagonal moorings are said to have some effect in lessening the motion of the bridge in high winds.

The plan proposed for Runcorn Bridge was, as already stated, to suspend the platform from iron cables, made of small bars, welded together at their ends, and bound up together, so as to form a long flexible bar or cable. That plan has not been adopted, the usual system being to make the chains of straight wrought-iron rods or bars, from 5 to 15 feet long, with either welded eyes or holes drilled out at their ends, by which they are connected together in pairs by short links and bolt-pins. This system was introduced by Captain Samuel Brown, R.N., who, in 1817, took out a patent for his invention. His reasons for preferring this mode of making the main chains to making them of links, like chain cables, or of small wires, were, that link chains are weaker in proportion to their weight than bars, a portion of the strength of the iron being lost in bending it into the form of a link; and small wires are inexpedient for large bridges, on account of the number of parts and complication of joinings required, and also on account of the great surface they expose to damp, and their consequent liability to destruction. The Union Bridge across the Tweed, five miles above Berwick, was the first large bar-chain bridge completed in this country. It was begun in August, 1819, and opened in July, 1820, just after the commencement of the Menai Bridge.

The straits of Menai, which separate the island of

LONDON, SOUTHWARK & BLACKFRIARS BRIDGES.

Anglesea from Caernarvonshire, had long formed a troublesome obstruction upon the great road from London to Dublin by Holyhead. The connexion between the two shores was maintained by six ferries, the most important of which was that about a mile north of certain rocks in the strait, called the *Swellies*, named *Bangor Ferry*, from its proximity to the city of Bangor. The idea had long been entertained of superseding the ferry by a permanent roadway; but no plan had been entertained until after the union of Ireland with England, when the increased intercourse between the two countries led the Government, in 1801, to direct Mr. Rennie to survey the strait, and prepare a plan and estimate for a bridge. Four designs were accordingly prepared for a cast-iron structure; and, while these were under consideration, a violent opposition was made to the erection of a bridge, by interested parties, and it was affirmed that the effect of a bridge would be to destroy the navigation of the strait. A parliamentary committee, however, reported that the bridge was desirable, and in no way likely to prove injurious; and they advised the immediate construction of the proposed bridge, with three cast-iron arches, over the Swellies. Upon this, the Lords of the Treasury directed Mr. Telford to survey the Holyhead Road, and to consider the best mode of passing the Menai Strait. This was done; and in April, 1811, Telford proposed a cast-iron bridge, of one arch, 500 feet span, 100 feet clear in height, at high spring tides, and 40 feet broad. As it was nearly impossible to construct the centering of the arch from below, on account of the nature of the bottom of the channel, and the great rise and rapidity of the tides, Telford proposed to suspend the centering from above.

This plan was strongly recommended for adoption by the parliamentary committee, in their report, in May, 1811; but the difficulties in which the country had been involved by the long protracted war abroad interfered with improvements at home, and nothing was done in the matter until 1818. In the interval, however, public attention had been drawn to the subject of suspension-bridges; and the improvements of the Holyhead Road being in active progress, in pursuance of an Act passed in 1815, under Telford's direction, he was ordered, in 1818, by Government, to give his opinion whether a suspension-bridge was practicable over the Menai Straits, and if so, to prepare a design. Telford accordingly surveyed the localities, and proposed a suspension-bridge at Ynys y Moch. Evidence was taken by the committee, at considerable length, on the plan proposed, and the opinions of engineers being favourable, a report was made, and 20,000*l*. voted by Parliament to enable the commissioners to commence operations; but, in consequence of the opposition of interested parties, the building of the bridge was delayed until July, 1819, when an Act was passed, giving proper powers for carrying on the erection of the bridge.

We come now to describe the finished structure.

	Feet.	Inches.
The distance apart of the centres of the summits of the main pyramids is	579	$10\frac{1}{2}$
The deflection of the chains in the middle	43	0
The clear height of the roadway above high water	102	0
Breadth of the platform . . .	28	0

It is divided into two carriage-ways, one on each side of the bridge, 12 feet wide, and a central footpath, 4 feet wide.

The piers of suspension are pyramids, built of grey Anglesea marble. The Anglesea main pier stands on the rock Ynys y Moch, which was levelled by blasting to form a foundation, and rises to about the level of high water. On the Caernarvon side the foundation of the pier is sunk 7 feet below the surface of the beach, and is also firm rock. The main piers are 100 feet high, from the level of high water line up to the level of the roadway, and their summits are 53 feet above the roadway. The shape of the piers below the roadway is octagonal; their extreme breadth at the base 70 feet, and at the summit 45 feet. Their thickness at the base is 50 feet, at the level of the roadway 29 feet, and at the summit 11 feet. They are not built solid all the way up; but, in each, four hollow squares, about $9\frac{1}{2}$ feet square, were left, commencing above high-water mark, and running up to within about 4 feet of the level of the roadway. Through each main pier two arched openings are formed for the passage of carriages, 9 feet wide, and 15 feet high to the springing of the arches, the wall between them being a little more than 6 feet thick. The masonry above the openings is tied together by iron dowels, 1 inch diameter, and 12 inches long, put through holes drilled through each stone of every course. To prevent the walls of the arches for the carriage-roads being pressed out by the weight of the superincumbent part of the pyramid, 6 wrought-iron tie-bolts, 4 inches wide by 2 inches thick, are laid in the masonry at the springing of the arches, with dovetail heads at each end, let into corresponding sockets in cast-iron plates bedded in the masonry. The main piers are connected with the shores by a series of arches, three on the Caernarvon side, and four on the Anglesea side. The height of each of the small piers, from high-water line to the springing of the arch, is 65 feet, and the span of each arch $52\frac{1}{2}$ feet. A square chamber is left in each, filled up with rubble.

The main chains are on Capt. Brown's plan of straight bars, A, Fig. 319, united by coupling bolts. The main chains are 16 in number, each containing a series of links composed of 5 wrought-iron bars, 9 feet $1\frac{1}{4}$ inch long, $3\frac{1}{4}$ inches broad, and 1 inch thick. They are disposed, four chains one under the other, on each side of the central footpath, and four at each outside of the platform. So that there are in all 80 bars in the main chains, and their united section is $80 + 3\frac{1}{4} = 260$ square inches of iron. The bars are united by coupling plates, B, Fig. 319, 16 inches long, $7\frac{1}{2}$ inches broad, by

1 inch thick, and screw-bolts, C, Fig. 319, 3 inches diameter, each bolt weighing 56 lbs. The main

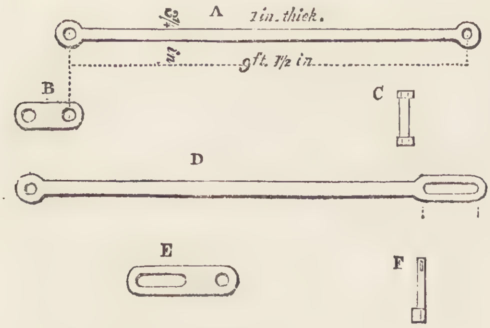


Fig. 319.

chains are carried through tunnels cut through the solid rock of which the shores are composed, and the extreme ends are fastened by strong holding bolts in chambers made at the ends of the tunnels. The holding bolts are 9 feet long and 6 inches diameter, and rest in sockets in cast-iron plates 6 inches thick. There are 12 holding bolts at each end of the bridge, viz. 4 for the two middle sets of chains, and 4 for each of the outer ones. The length of each bolt between its bearings against the rock is 18 inches. There are 3 tunnels for the chains, about 5 feet square, at each end of the bridge, viz. one for the two central sets of chains, and one for each of the outer ones. The bars of the chains in the tunnels are much stronger than the other bars, under the idea that in the tunnels they would be more exposed to rust, and less accessible for painting or varnishing them. The back stays are tied down, by vertical rods, to small cast-iron plates laid in the masonry of the arches between the main piers and the shores, to prevent their undulation.

Thus the main chains are fixed firmly at their extremities into the rock, and are also held down between the main pyramids and the shores: but over the pyramids they lie loosely upon cast-iron saddles, laid upon horizontal rollers or trucks, 3 feet 8 inches long and 8 inches diameter, that lie in grooves or channels formed in a cast-iron platform upon the summit of each main pier. The saddles can thus move backwards and forwards a few inches in the direction of the length of the chain, and hence expansion and contraction of the chains produce no other effect than to move the saddles on which they lie, just as much as they lengthen or shorten, and to raise or depress the suspended roadway a little, instead of producing an injurious strain on the materials. The rollers on which the saddles rest, are kept equidistant by their necks or projecting ends being received in brasses held between wrought-iron plates screwed together, so that no one roller can move alone; but there is sufficient space in the grooves in which the rollers are placed, for all of them to move as much as 4½ inches.

The chains are tied together across the breadth of the bridge by transverse ties, which are cast-iron tubes placed between each pair of chains, with wrought-iron screw bolts put through them, and passing through the chains. The bolts serve to draw the chains together by their nuts, and the cast-iron tubes keep the chains a proper distance apart. There are 8 of these transverse ties in the length of the bridge. The chains are further tied together by a diagonal wrought-iron lacing between each pair of transverse ties. This mode of binding the chains was adopted in consequence of the effect perceived on them from the action of gusts of wind, while the bridge was in progress.

In the length of the chains there are 4 sets of adjusting links to every line of chains, viz. 2 in the opening between the piers, and 1 between each pier and the shore. The object was, to give the means of adjusting the chains to their proper length, in case there should be any inequality in the lengths of the bars. Fig. 320 is a perspective view of one of the adjusting links, and D E, Fig. 319, is a side view of the same. At one end of each of the bars *a*, a long

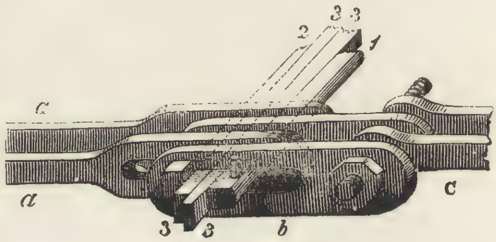


Fig. 320.

hole is made instead of a round eye, and the corresponding end of the connecting plate *b* has also a long hole in it. The bar and connecting plate are connected by two semicircular pins, 1 and 2, one bearing against the ends of the bars *a*, and the other against the ends of the connecting plates *b*, Fig. 320, and E, Fig. 319. and the space between them is filled up with iron wedges, 3,3. If any one of these iron wedges be taken out, the ends of the bars *a* can be drawn away a little from the ends of the connecting plates *b*, and so the chain will be lengthened; or by driving in more wedges, the two semicircular pins, 1, 2, are separated further and the chains shortened. The bars C are connected to the other ends of the connecting plates *b*, by screw bolts, like the other bars of the chain. The whole distance that each adjusting link can be lengthened is 9½ inches: so that as the chains can be lengthened 19 inches between the pyramids, and 9½ more between each pyramid and the shore, allowance is made for 38 inches in all.

The roadway is laid upon wrought-iron cross-bars or roadway bearers, suspended from the ends of the vertical suspending rods. The bearing bars are 3½ inches deep, and ½ inch thick, placed 1 inch asunder, and the space between them is filled up with a piece of deal. They are trussed with bent ties and struts underneath. The roadway consists of two thicknesses of fir plank, the lower one of 3 inches, the upper one of 2 inches, laid parallel with the length of the bridge, upon the iron cross bearers. The lower course is bolted to the wood that is riveted between the iron

roadway bars, and is covered with patent felt saturated with boiled tar; the second course of planking is spiked through to the lower course. In the middle of each carriage-way a third course of planking, 2 inches thick, is spiked through to the second, through an intermediate layer of felting; and an oak guard is bolted on each side of the carriage-way through the two lower courses of planking. Also to stiffen the roadway, an oak plank is bolted to the underside of it between each of the cross bearers.

All the suspended iron-work of the bridge, before being put up, was proved by actual strain in a proving machine, at the rate of 11 tons strain per square inch.[1]

The chain-work was put up in the following manner. The chains were first put together in the tunnels, working up from the fastenings to the mouths of the tunnels, by bringing down one link of each chain at a time, and bolting it to the one previously brought down. The chains were then put together from the mouths of the tunnels up to the main piers, upon a scaffolding erected on the masonry between the pier and the shore, with the proper inclination for the back stays. The chains were then continued over the Caernarvon pier, and allowed to hang loosely down to the level of high water. This was done by suspending a cradle large enough for two men to sit in, from a crane-arm set up on the top of the pyramid. The cradle was suspended by tackle, so that the men could slack it down or haul it up, to raise or lower themselves at pleasure. The links of the chain that were to be joined on to the ends of the hanging chain, were brought in succession along the road to the front, or the sea face of the pyramid, through the arched roadway opening. The link was then taken up by tackle from a pair of shears placed on the top of the pyramid, and lifted up to the height of the link it was to be fixed to, where the men in the cradle got hold of it and brought the two links together, and put the coupling bolt through them.

On the Anglesea side of the street the chains were carried just over their saddles on the top of the pier, and their ends were retained by tackle made fast to them, and descending thence to capstans on the shore. The remaining piece or length of chain which was to unite the two ends of the chains brought up from each shore, was laid on a raft, 400 feet long, and 6 feet wide. One end of that piece of chain was first attached to the end that hung down to the water from the Caernarvon pier, and then the raft was floated across to the Anglesea pier, and the loose end of the chain upon it was fastened to the tackle which hung down from that pier. The tackle was then hauled up by the capstans fixed on the shore, and the chain was gradually raised off the raft until the end of it was brought in contact with the end of chain that hung over the top of the pier. The two loose ends were then bolted together and the operation completed. The first chain was thus raised and fixed on the 26th May, 1825, in 1 hour 35 minutes. The other 15 chains were successively got up in the same way at subsequent periods, the second chain being got up on the 28th April, and the fifteenth on the 28th June.

The hoisting of the first chain is thus described by Mr. Provis, the resident engineer:—"Whilst these operations were going on below, [*i.e.* securing the two ends of the chain at the Caernarvon pier,] the two capstans were manned by about 150 labourers, and everything above put in readiness. The word "go along" was then given, when a band of fifers struck up a lively tune, and the capstans were instantly in motion. As soon as each main fall or leading rope had coiled from the bottom to the top of its respective capstan barrel, the capstans were stopped, the clams screwed hard down upon the main falls, and held there till the ropes were shipped (or fleeted) down, from the tops to the bottoms of the barrels. The clams were then unscrewed, a fresh tune struck up, and the men resumed their task with renewed spirit. At first they had little to do but haul up the slack of the tackles, but when these were tightened, and the weight of the chain, which was gradually rising, began to be felt, the race which they had hitherto run at the capstans was reduced to a steady trot. Before the chain was lifted quite off the raft, the direction of the tide had changed, and the anchors being all on what was the up-stream side of the raft when it was moored, were of no use now in resisting the force of the contrary current. The raft was consequently forced from under the middle of the chain, which swung easily off into the water. Till this time scarcely a word had been heard but the directions to 'hold on' or 'go along,' but as soon as the chain was fairly suspended above the surface of the water, we were greeted with a hearty cheer from the surrounding crowd. As soon as the raft had drifted from under the chain, the anchors were weighed; the ropes which held to the ringbolts at the Caernarvonshire pier were slacked to give the raft sufficient play, and in a few minutes it was floated to its berth on the shore and secured in readiness for another chain." Many of the strangers assembled to witness the operation were eager to relieve the workmen at the capstans, "anxious to have it in their power to say they had helped to put up the first chain of the Menai Bridge." The whole

(1) The proving machine was similar to that used by Captain Brown. It consists of two rollers set up in bearings, one at each end of a long iron frame. On the axis of one of the rollers a strong lever projecting out horizontally is fixed; its end is connected, by a short vertical link, to the short end of a counter horizontal lever mounted on a fixed centre-pin; the long end of this lever is loaded, the proportions of the levers being such, that a very moderate weight on the end of the counter lever, will exert great power to turn the roller round. A short vertical arm projects out below the circumference of the roller, to which a piece of chain is linked. One end of the bar to be proved, is fastened to the end of that chain, and the other end is linked to a chain attached to the opposite roller. This second roller is turned round by 2, 4 or 6 men, according to the size of the bar under proof, by means of a train of 3 wheels and 3 pinions, until the loaded roller is pulled or turned round enough to raise up its balance weight, which is the measure of the strain the bar is intended to undergo. In the machine used at Capt. Brown's manufactory, the proportions of the two levers were such as to multiply the effect of the balance weight 224 times, and the train of wheelwork was so proportioned, that two men at the handles could exert a force of 30 tons on the bar under proof.

operation was conducted in the most satisfactory manner. "Every man was at his post and anxious to do all he could to ensure success. Not the slightest accident, nor even a single blunder, occurred from the time of casting off the raft till the chain was secured in its place. Mr. Telford now ascended the pyramid to satisfy himself that all was right; and there, surrounded by his assistants, the contractors and as many as could find a place to stand on, received the congratulations of many a friend to the Bridge. The hats on the pyramid were soon off, the signal was understood by all around, and three cheers loud and long closed the labour of the day. The ceremony was scarcely over when one of the workmen got astride the chain, and passed himself over it to the opposite side of the Strait. Another followed soon after and actually had the temerity to raise himself up and walk over 30 or 40 feet of the middle of the chain, though the slightest slip must have sent him to destruction; the chain being only 9 inches wide, and its height at that time above the surface of the water not less than 120 feet." [1]

It is related in the appendix to the Autobiography of Telford, (London, 1838,) that after the second chain was got up, a labourer, after finishing his day's work, sat himself down quietly on the centre of the curved part of the upper suspension chain, with his feet resting on the one below it, and in that position actually went through the regular operation of making a pair of small shoes in the short space of 2 hours: he afterwards sold the shoes for a sovereign, and was led to suppose that they were purchased for public exhibition at the British Museum.

The hoisting tackle consisted of two ropes, each leading from a capstan fixed on the shore between 400 and 500 feet back from the pyramid, and there passed over two pulleys 14 inches diameter, fixed in a strong frame placed on the top of the pyramid. Hence the ropes passed through a block of four sheaves made fast to the end of the piece of chain on the raft. Hence the rope led up again through a three-sheaved block at the top of the pyramid, lashed to one of the chains of the back-stays, and lastly, through a single-sheaved block made fast to the end link of the chain hanging over the summit of the pyramid, to which the end brought up from the raft was to be attached. The barrels of the capstans were 1 foot 8 inches diameter; the axles about 4 inches diameter, worked by 8 spanners of 10 feet radius, and manned by about 150 men for the two.

The bridge was opened on the 30th January 1826, or $6\frac{1}{2}$ years after its commencement; several improvements and alterations were made during the summer months of 1826, in order to stiffen the chains and roadway. There is no perceptible transverse vibration of the roadway: the vertical undulation before the introduction of the transverse ties and diagonal lacing was about 18 inches, but afterwards it was not found to exceed 6 inches. The chains are scraped and painted once in 3 years. The longitudinal motion on the pyramids by expansion and contraction of the chains has been observed to the extent of 2 inches.

	Tons	Cwt.	qrs.	lbs.
The weight of the 16 main chains between the points of support, including connecting plates, screw pins, wedges, &c. is computed at . . .	394	5	0	16
The transverse ties	3	16	2	20
The weight of the suspending rods and platform, viz. roadway bars, planking, side-rails, iron-work, &c.	245	13	2	27
Making the total suspending weight	643	15	2	7

Whence the tension of the iron at each point of suspension is by the weight of the bridge itself, according to experiment,[2] 1.7 times 643 ,, 15 ,, 2 ,, 7 = 1,094.42 tons.

The entire section of the 80 bars is $80 \times 3.25 = 260$ square inches, which would bear without breaking $260 \times 27 = 7{,}020$ tons.

According to Telford's experiments, about half the breaking strain, or 3,513 tons, would produce permanent elongation; and if we take the standard of 9 tons per square inch, the chains will bear constantly without any risk $9 \times 260 = 2{,}340$ tons or $2{,}340 - 1{,}094.42 = 1{,}245.5$ tons of strain produced by the weight of the bridge itself. Therefore it may be perpetually loaded without any injury with $\frac{1245.5}{1.7}$ or about $732\frac{1}{2}$ tons besides its own weight.

Such are the details of the Menai Suspension Bridge. Few works connected with the profession of a Civil Engineer have excited more interest, "for," as Mr. Provis remarks, "though the principle of its construction is old as the spider's web, the application on a scale of such magnitude, the durability of the materials of which the bridge is composed, and the scientific combination of its various parts, render it one of the noblest examples of British skill. As a public convenience too, it is of the highest importance; for instead of an uncertain ferry over an often tempestuous strait, at all times crossed with trouble and delay, and frequently at the risk of life, a commodious roadway has now been established between its shores, that can be passed at all times with safety and comfort."

The Conway Suspension Bridge was built to replace a ferry across the estuary between the town of Conway and the opposite shore that leads to Chester, and to connect by a safe and permanent road across

(1) "An Historical and Descriptive Account of the Suspension Bridge constructed over the Mênai Strait," &c. By W. A. Provis, the Resident Engineer. London. 1828

(2) Before suspending the main chains experiments were made by Mr. Rhodes to find the tension required to draw them up to the required curvature. They were tried with a chain made of some of the vertical suspending rods 1 inch square, with a chord line of 570 feet, and deflections varying from 35 feet to 49 feet. He found the tension of the chain at 43 feet deflection, viz. the intended deflection of the chains = 6,134 lbs. The weight of the chain was 3,599 lbs.: hence the tension was 1.7 times the weight suspended.

that estuary the towns of Bangor and Chester. It was commenced in 1822, and completed in 1826, and differs but little in construction from that of the Menai Bridge. The chains, however, were put up in a different manner. A temporary rope bridge was made with the ropes used for the hoisting tackle at the Menai Bridge; and on that the chains were put together in the places intended for them; after which the ropes were slacked and the chains adjusted to their proper tension. The distance between the points of support is 327 feet, the deflection $22\frac{1}{3}$ feet, and the height of the under side of the roadway above high-water of spring tides is 15 feet.

About the time when the Conway Bridge was begun, the Brighton Chain Pier was commenced by Captain Brown in October 1822, and was opened in November 1823. It runs out into the sea 1,014 feet from the face of the esplanade wall. The entire length of the bridge is 1,136 feet, in four openings, each of 255 feet span and 18 feet deflection. The extreme breadth of the platform is 13 feet, and the clear breadth 12 feet 8 inches. The suspension towers consist of pyramidal cast-iron frames, one on each side of the bridge, united by an arch at the top. They are 25 feet high, 10 feet apart, and weigh each about 15 tons. They stand on clumps of piles driven about 10 feet into the chalk rock that forms the bed of the sea, and rising 13 feet above high water. The clump of piles at the outer end or pier head is in the form of the letter T, and contains 150 perpendicular piles besides the diagonal piles, framed strongly together with walings and cross braces. On them a platform is laid 80 feet by 40, paved with a course of Purbeck granite. The three other clumps contain each 20 piles, besides the diagonal piles. The platform is supported by 4 chains on each side of the bridge, arranged two in breadth and two in depth. They are of wrought-iron round eyebolts about 2 inches in diameter, 10 feet long, and united by open coupling links and bolt-pins. They rest upon saddles on the upper part of the suspension towers. The chains on the land-side are carried over a suspension pier of masonry, and the back stays are carried through two tunnels in the cliff and properly secured. The back stays at the pier head are fastened to the diagonal piles. The platform is suspended from the main chains by vertical suspending rods 1 inch in diameter and 5 feet apart, viz. one at every coupling of the chains. At their upper ends they are formed with a cross or T head, Figs. 321, 322, which is supported by a cap resting upon the ends of

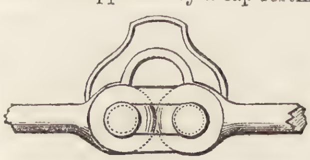


Fig. 321.

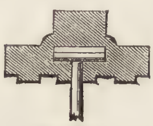


Fig. 322.

the main chains and coupling links, one cap at every coupling. A square cavity or chamber is cast in the lower part of each of the caps, with an oblong slit or entrance, through which the T head of the vertical rod is put upwards, and being turned round in it across the slit, is borne up by the cap as shown in Fig. 322. The lower ends of the vertical rods spread out into forks, which clasp over and are fastened by cross pins to a longitudinal side bearer made of bars of flat iron, bolted together and extending from tower to tower. On the side bearers are laid cross joints $7\frac{1}{2}$ inches deep by $3\frac{1}{2}$ thick, and over these is laid a course of planking for the roadway. The platform is guarded and stiffened by an iron railing or parapet.

Considerable difficulty was experienced in driving the piles, on account of the hardness of the bed of the sea, and the storms which are common on that coast. The work, however, was completed, and the pier continued during many years to render its useful services. It withstood the shock of many a violent tempest; but at length, in November 1836, it yielded to a gale of wind. The roadway of the pier gave way half an hour after mid-day of the 29th, about which time Osler's anemometer recorded the pressure caused by the wind's force at Birmingham as equal to $11\frac{1}{2}$ pounds on the square foot. The barometer at Greenwich had sunk to 29.24; the wind's force there also being denoted by $11\frac{1}{2}$. There was a double motion in the pier, for both chains and roadway oscillated laterally, and undulated longitudinally; but the latter movement increased greatly, whilst the former diminished, just before the fracture took place.

Fig. 323. THE BRIGHTON CHAIN-PIER, AFTER THE STORM OF THE 29TH NOV. 1836.

It was probably owing to this double motion that half the upper part of the roadway, and half the under part, were visible to the spectators at the same instant. As soon as the side-rails gave way, the undulations greatly increased, and almost immediately afterwards the roadway broke. It was remarked at the time that, had the side-railing been a trussed rail, the pier would probably have withstood the force of the storm. Fig. 323 is a sketch of the ruins of the pier after the accident.

The suspension bridge at Montrose was blown up by the hurricane of the 11th October, 1838. Colonel Pasley, who was sent to inspect the bridge, remarks, that "it was blown up from below; it being, like our English roofs, rather resting by its own weight than secured against hurricane action. The bridge at

Montrose had nothing to stiffen it longitudinally in a vertical direction. Iron transverse beams, supported by the rods, had two tiers of planking over them, and a light railing on each side, like that of a common balcony. The suspension bridge at Hammersmith, on the contrary, has railing of strong iron posts, and the rest of wood, on each side; and two longitudinal sets of king-post trusses on each side of the carriage-way, and between it and the footpaths."

Mr. Rendell was employed by Government to repair the chain bridge at Montrose. The manner in which he proposed to truss the bridge, to prevent a recurrence of the same misfortune, is here shown. Fig. 324 is a longitudinal section of the trussed rail, which,

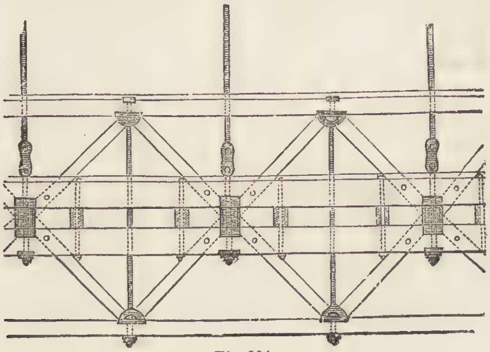


Fig. 324.

it will be seen, passes below the bridge as well as above it; and Fig. 325 is a transverse section, showing cross-bracing at every 35 feet, below the roadway.

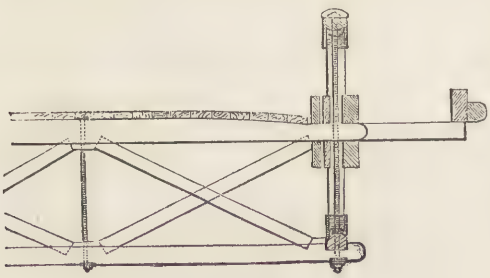


Fig. 325.

Our limited space will not admit of any details respecting the many beautiful suspension bridges which have been erected in this country and elsewhere since the opening of the Menai Bridge. The Hammersmith Suspension Bridge, by Mr. W. T. Clarke, and the Hungerford Bridge, will repay an attentive study on the part of those interested professionally in these subjects. The former is described in Mr. Drewry's work, together with a number of other bridges, either proposed or actually erected, up to the date of its publication, in 1832.

Some of the French engineers have preferred wire to bar-iron for suspension bridges. The reasons given by them for this preference are, that iron wire is stronger than bar-iron; that cables of wire can be put together more easily and rapidly than chains; that it is more easy to ascertain whether it be sound or not; and, that it is easier to get wire cables up into their places than bar-chains.

The facility of working wire, without heavy machinery, may render its use expedient in small structures; but it has many disadvantages for larger ones. First, as Mr. Drewry states, "although a single wire is stronger per square inch than a bar of iron, it is much to be doubted whether a cable made of wires is stronger than a bar-chain of equivalent dimensions, because of the inequality of tension in the several wires, which throws a greater share of strain on some than on others, and therefore reduces the effective length of the cable to that of a cable of less diameter. This inequality it is hardly possible to prevent, even if the wires are drawn, in making up the cables, to the same curvature that they are intended to have when in their places. Secondly, wires, exposing a greater surface than bars of equal section, are more quickly destroyed by oxidation. A coating of varnish, it is true, may somewhat preserve them; but bars may also be preserved by varnish and painting, and are still on that point superior to wire cables. Thirdly, wires are very apt to have kinks and bends in them, which cannot be got out without a very considerable strain; and when that has been done, it is difficult to ascertain whether the wire has not been permanently injured at that part. The long bends, also, that are formed frequently in wire can hardly be got rid of at all. . . . Lastly, although a small cable is very easily got up into its place, it is so, not because it is a cable, but because it is comparatively small and light."

In 1823, a wire bridge was erected over the double ditch of the fortifications at Geneva. The wires were of small size, laid together side by side, and bound up into small cables by wire wound spirally round them. It was erected under the direction of Colonel Dufour, an officer of engineers, at the cost of little more than 640*l*. The inner ditch is 109 feet wide, the outer one $75\frac{1}{2}$ feet wide, and the embankment or counterguard between the two $82\frac{1}{2}$ feet wide. The breadth of each opening is 131 feet clear between the piers, which are of masonry. The main cables pass over the piers in grooves formed in bed stones on the tops of the piers: the edges of the grooves are rounded off where the cables come on them, and are covered with a thin brass plate. The ends of the cables at the tower end are attached to vertical bars, $7\frac{1}{2}$ feet long, and $1\frac{5}{8}$ inch square, which descend close against the back of the pier; their lower ends are linked to horizontal bars laid on edge in the foundations of the piers. The back stays being thus carried down perpendicularly, this pier has to bear all the drag of the bridge to pull it over, and is made larger and stronger than the others in proportion. At the opposite end of the bridge, the cables are fastened to inclined bars. The cables are in several lengths, there being one long cable across each opening, and three short ones over each pier. By varying the different lengths of the short connecting cables that lie on the tops of the piers, the main cables are adjusted. The ends of the long cables are fastened to the short ones by wire links, Fig. 327; loops at the ends of the cables are made like the loop of a cord, by simply turning the wires back upon themselves, and then binding the

Fig. 326. WIRE SUSPENSION BRIDGE OVER THE NIAGARA RIVER.

loose ends of the cable together by a wire wound tight round them at *a a*. The cables I and L are

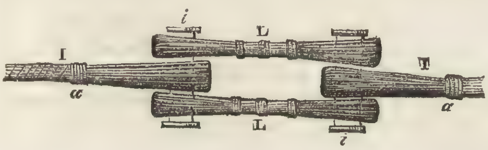


Fig. 327.

united by bolt-pins, made hollow, that they may be of large diameter without being heavy. Where the cables are looped round the ends of the iron bars for the back stays, *b*, Fig. 328, a small semicircular brass

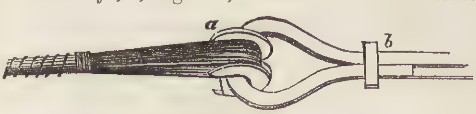


Fig. 328.

washer *a* is interposed, to prevent the wire being bent too abruptly.

The platform consists of cross joints suspended from the main cables by short vertical cables, each containing 12 wires. The upper ends are looped round the main cables, and the ends tied round by a wire, in the way described of the loops at the end of the cables; and the lower ends are simply looped round the ends of the cross joints, and also tied. The parapet is $3\frac{1}{2}$ feet high, composed of small iron rods, with a top rail, and two other rails of flat iron. The parapet is inside the suspension wires, to guard them from injury. It is steadied by diagonal ties, about 25 feet from each end.

The load on the larger opening is thus calculated:—

160 persons	23,205 lbs.
Weight of bridge, platform, &c.	15,912
Chains, &c.	1,547
Chance load	221
	$40,885 = 18\frac{1}{4}$ tons.

The angle of direction of the chains is 19°, and the tension for that angle is about 1.5 times the weight $= 27\frac{3}{8}$ tons. The ultimate strength of the cables is $111\frac{1}{2}$ tons, and they might be safely loaded with one-third of that, or 37 tons, instead of $27\frac{3}{8}$. The bridge vibrates very much from the great slackness and lightness of the construction. It is well adapted for its purpose, being intended only for foot passengers; but it would be dangerous to allow it to be completely loaded, or to allow more than 50 men to march over it in step.

The most remarkable wire suspension bridge in Europe, on account of its dimensions and height, is that of Freyburg, in Switzerland, commenced by M. Chaley, of Lyons, in the spring of 1832, and opened to the public on the 23d August, 1834. This bridge has a span, from pier to pier, of 870 feet, and is suspended at the height of 167 feet above the river which flows under it. It is thus 319 feet longer than the Menai Bridge, and 65 feet higher. "It is supported on 4 cables of iron wire, each containing 1,056 wires, the united strength of which is capable of supporting three times the weight which the bridge will ever be likely to bear, or three times the weight

of two rows of waggons extending entirely across it. The cables enter the ground on each side obliquely for a considerable distance, and are then carried down vertical shafts cut in the rock, and filled with masonry, through which they pass, being attached at the extremity to enormous blocks of stone. The materials of which it is composed are almost exclusively Swiss. The iron came from Berne; the limestone masonry from the quarries of the Jura; the woodwork from the forests of Freyburg; the workmen were, with the exception of one man, natives, who had never seen such a bridge before. It was completed at an expense of about 25,000*l.* sterling, and, in 1834, was subjected to various severe trials, to prove its strength. First, 15 pieces of artillery, drawn by 50 horses, and accompanied by 300 people, passed over it at one time, and were collected in as close a body as possible, first on the centre and then at the two extremities, to try the effect of their concentrated weight. A depression of $39\frac{1}{3}$ inches was thus produced in the part most weighed upon; but no sensible oscillation was occasioned. A few days after, the bridge was opened by the bishop and the authorities of the town, accompanied by about 2,000 persons, who passed over it twice in procession, preceded by a military band, and keeping step. On this occasion a slight horizontal vibration was produced; but it is very improbable that the bridge, in its ordinary service, will ever receive such a multitude at once. The passage of 2 or 3 heavy carriages or carts across it causes only the slightest perceptible oscillation; and nothing is more extraordinary in this beautiful structure than the combination of stability with such apparent fragility."[1]

We learn from the same authority that another wire bridge, 640 feet long and 317 high, has been suspended across the gorge of Gotteron. It was finished in 1840. The wire cables are attached immediately to the solid rock on each side, and the point of suspension is higher on one side than on the other, which gives it the appearance of half a bridge. The object of this mode of construction was economy, the expense of building piers of masonry from the bottom of the valley being thus saved.

But even the Freyburg Suspension Bridge has been excelled by a wire bridge recently constructed over the Niagara River in North America. It is built over the river at a point about $1\frac{3}{4}$ mile below the Falls, and directly over the fearful rapids which commence at this point. The bridge is nearly 800 feet in length, and is suspended 260 feet above the river. Upon the very edge of the precipice which bounds each shore of the river towers 80 feet high have been built, and at a point about 100 feet in their rear the immense wire cables which sustain the bridge are firmly secured. These strands pass from their fastenings immediately over the top of the tower upon either cliff; they pass thence across the chasm, and then over the top of the tower upon the opposite shore, in the rear of which the ends are fastened into the rocks. Two of these powerful cables, one on each side, support the bridge. "Stepping upon the bridge, before you walk 20 feet from the shore you find yourself suspended in the air several hundred feet above a mass of jagged and flinty rocks over and among which the waters of Niagara plunge with terrific velocity. To add to the sensations of terror which this fearful scene is calculated to produce at first glance, you find the bridge oscillating and bending beneath your weight. It requires considerable nerve to cross this aërial structure, and there are few who have firmness enough to look over the side into the awful surf. The bridge is about 10 feet in width, and a temporary railing of wire and slats of wood has been constructed at each side. The flooring is composed of light planks resting upon thin scantlings, to which the wires are fastened."[2]

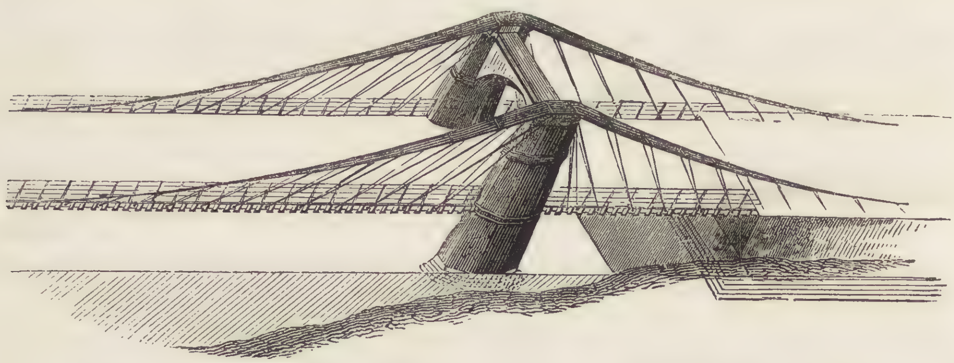


Fig. 329. ISOMETRICAL VIEW OF ONE HALF OF A SUSPENSION BRIDGE ON MR. DREDGE'S PRINCIPLE.

Mr. Dredge of Bath has adopted a new and elegant principle in the construction of suspension bridges, which promises to be of great use, both as regards the quantity of material employed, and the stability and strength which it confers on the structure. In this invention the chains are made of sufficient magnitude and strength at the points of suspension, to support with safety the greatest permanent and contingent load to which they are ever likely to be exposed; and from thence they taper or diminish gradually to the middle of the bridge, where the strain becomes least. The suspending rods or bars that

(1) Murray's "Handbook for Travellers in Switzerland," &c. See also Penny Magazine, Nos. 279, 280

(2) "New York Herald," quoted in the "Athenæum," Sep. 30 1848.

support the platform, instead of being hung vertically, or at right angles to the plane of the horizon, as is usually done, are inclined to it in angles which vary in magnitude from the abutments to the middle of the bridge, where the obliquity, as well as the stress upon the chains, attains its minimum value. "The principle developed by this obliquity of the suspending rods is singularly beautiful; but much judicious management is necessary on the part of the engineer, to fix upon that degree of obliquity which shall produce the greatest effect. Each bar is considered to perform its part in supporting the load, in proportion to its distance from the abutment, drawn into the sine of the angle of its direction, so that the entire series of suspending bars transmits the same tension to the points of support as would be transmitted by a single bar reaching from thence to the middle of the bridge." [1]

Fig. 329 represents a portion of the bridge at Balloch Ferry, Loch Lomond, erected on this principle. Several of Mr. Dredge's bridges have also been erected in the Regent's Park, London.

Section VI.—On Iron, Girder, and Tubular Bridges.

The extensive employment of iron at the present day, is one of the consequences of the improvements which have taken place in its manufacture, as well as the increased facilities for transit afforded by canal navigation, roads, railroads, and other means of conveyance. It is scarcely more than 70 years ago, that the first iron bridge was constructed in England, over the river Severn, near Coalbrook Dale. It consists

Fig. 330. Iron bridge at Coalbrook Dale.

of 5 ribs of cast-iron supporting perpendicular spandril pieces of the same material, and upon which the roadway is carried. The arched ribs are nearly semicircular, having a span of 100 feet and a rise of 45 feet. The arches spring at a height of 10 feet above low-water level, so that the clear height up to the soffit of the arches is 55 feet. The form of this bridge is well adapted to the high banks of the Severn, at the place where it crosses. The bridge was built by Darby, but the design appears to have originated with Mr. Pritchard.

In 1787, Thomas Paine presented to the Academy of Sciences, at Paris, a model of an iron bridge constructed by him; and in the following year, during his residence at Rotherham in Yorkshire, a bridge chiefly of wrought-iron is said to have been erected, but was afterwards taken down.

In 1790 Mr. Rowland Burdon designed a cast-iron arch for the River Wear at Sunderland, on a peculiar

Fig. 331. Iron bridge at Sunderland.

plan of construction, for which he obtained a patent. It consisted in "a certain mode or manner of making, uniting and applying cast-iron blocks, to be substituted in lieu of key-stones in the construction of arches." In this way it was proposed to retain the common form and principles of the old stone arch. The Sunderland bridge consisted of six ribs, 200 feet in span with a rise of 30 feet. The total height from low-water level to the soffit of the arch is nearly 100 feet, and the design is peculiarly elegant and bold. The six ribs which form the arch are parallel to each other, and 6 feet apart. Each rib consists of 105 separate blocks or castings, 5 feet in depth, connected together with bars and collars of malleable iron. The ribs are braced together with cast-iron tubular braces and struts. The spandrils are filled in with cast-iron circles, Fig. 332, meeting at their peripheries, and supporting the roadway, which is formed upon a strong timber frame, planked over and covered with a mixture of chalk and tar, upon which is placed a layer of marl, limestone and gravel. The bridge is 30 feet wide; the abutments are of stone founded on rock, and are 24 feet thick, and from 37 to 42 feet wide. The iron work consists of 214 tons of cast, and 46 tons of malleable iron. The bridge was completed within three years, at a total cost of 26,000*l*. In October 1816, it was disposed of in a lottery for 30,000*l*. The confined situation of the site rendered it necessary to erect the bridge without interrupting the passage of

(1) The Mathematical principles of Mr. Dredge's Suspension Bridge are investigated in a Supplementary Paper to Vol. i. of Mr. Weale's large work on bridges.

ships with their rigging standing. For this purpose, a perpendicular scaffolding was raised upon piles in the middle of the river, a sufficient space being left

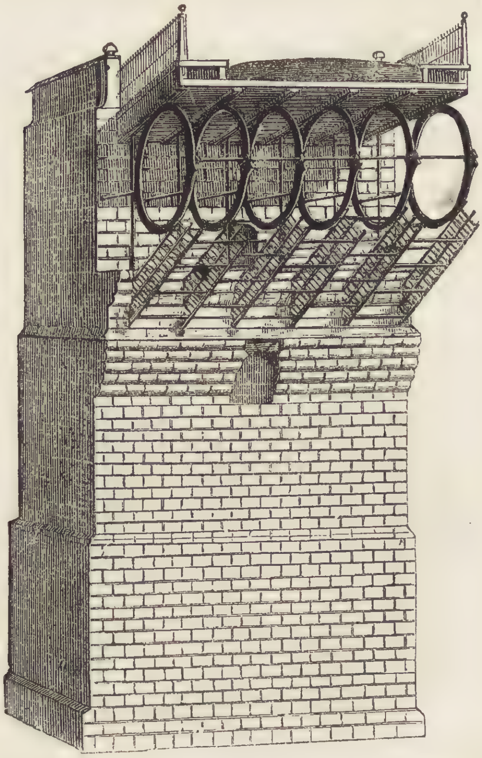


Fig. 332. SECTION OF THE IRON BRIDGE AT SUNDERLAND, 20 FEET FROM THE NORTHERN ABUTMENT.

on each side for the vessels. The centre for supporting the arch was fixed on this scaffolding. Some time after the centre was removed, the arch was found to have moved in a horizontal direction eastward, forming a curve of 12 to 18 inches versed sine. This dangerous and unexpected occurrence was skilfully counteracted by introducing transverse and diagonal tie-bars and braces, assisted by screws and wedges, by which the whole was restored to its original position.

Several iron bridges were erected by Telford, the first of which was that across the Severn, at Buildwas, in Shropshire, consisting of a single arch, 130 feet in span, with a versed sine or rise of 27 feet. The arch consists of 3 ribs, 9 feet apart, or 18 feet wide from out to out. These ribs are 3 feet 10 inches in depth, and connected transversely by tie-bars. The spandrils for supporting the roadway are formed of vertical bars of cast-iron, and the abutments are of stone.

The largest iron-arch bridge is the Southwark Bridge over the Thames, at London. It was designed and erected by Rennie. It consists of 3 arches, all segments of the same circle; the centre arch being 240 feet in span, with a rise of 24 feet, and the two side arches being each 210 feet in span, with a rise of 18 feet 10 inches. The piers are 24 feet thick; the width of the roadway over the bridge is 28 feet, and the footways on either side are each 7 feet in width. Each arch consists of 8 ribs, and each rib of 15 pieces, of such a depth that the rib is 6 feet deep at the crown, and 8 feet deep at the springing. The metal is $2\frac{1}{2}$ inches thick in the middle, and $4\frac{1}{4}$ inches at the top and bottom of the ribs. The ribs are connected transversely by cast-iron tie-braces, of the same depth as the ribs, but open in the centre of each; and in the diagonal direction the ribs are connected by another series of ribs, so that each arch consists of a series of hollow masses or voussoirs, similar to those of stone bridges. All the segmental castings forming each arch, as well as the transverse and diagonal tie-braces, are kept in their places by dovetailed sockets, and long cast-iron wedges, thus obviating the necessity for bolts. The spandrils are composed of cast-iron diagonal framing, and the roadway is formed upon cast-iron plates, resting upon the spandrils, and joined with iron cement. The abutments and piers are of stone, built upon platforms of timber, and surrounded by guard or sheathing piles, driven into the bed of the river. In the erection of the bridge, the ribs were commenced in the centre of the span, and continued regularly on both sides towards the piers and abutments. Upon these, connecting and bed plates were secured in the masonry, and when the last segment of each rib was fixed, 3 wedges of cast-iron, each 9 feet long and 9 inches wide, were introduced behind each rib, and nicely fitted and adjusted to them. These wedges were formed with a very slight taper, and were driven simultaneously with heavy hammers, so that the arches were nearly lifted from the centres, which were thus readily removed. The whole of the iron-work had been so carefully prepared, that, when the work was completed, scarcely any sinking of the arches could be detected. It was found, from experiments made during the progress of the works, that the average effect of the expansion caused by the summer increase of temperature was a rise of the arches, to the extent of about $1\frac{1}{2}$ inch at the crown, the abutments being fixed points. The weight of metal in the centre arch was 1,665 tons; in the two side arches, 2,920 tons; making a total of 4,585 tons. The first casting for this bridge was run on the 1st January, 1815, and the bridge was opened 25th March, 1819.

Iron-arch bridges are the same in principle as arch-bridges of stone and other materials, which derive their strength and stability by transferring the effect of the loads placed upon them to the abutments. But "when the peculiar properties of cast-iron had been studied, with a view to its extended application in buildings, and the proportions had been correctly determined for beams of this material, intended to supersede horizontal beams of wood, their employment in the formation of bridges of limited span soon followed; and in the railway works executed during the last twenty years, we have numberless examples of cast-iron girder-bridges, as we have also of cast-iron arch-bridges, of considerable dimensions, and great ingenuity of design and arrangement. The cast-iron girder-bridge, depending for its strength upon the sectional area of the girder, at that point in its

length over which the weight or load acts, requires abutments to resist vertical pressure only; while the abutments of arch-bridges have to resist the lateral thrust of the arch. In the cast-iron girder-bridge, moreover, the depth of the structure is reduced to that of the section of material due to the maximum load; and hence the peculiar applicability of this form for railway bridges, in which it is desirable to preserve a minimum distance from the under side or soffit of the girder to the level of the roadway above. But the limitation of span to which girders are safely applicable has always restricted their employment in bridges, and 40 feet has commonly been considered the maximum length of bearing to which single cast-iron girders can be safely applied, liable to be loaded with railway trains, or other heavy weights." [1]

The desire to retain this convenient form of structure, and to extend its use to larger spans, has led to attempts to combine wrought-iron with cast metal; malleable-iron bars or rods being fitted to cast-iron girders, so as to form a kind of metal trussing, the depth of the truss being limited to that of the girder. But the great defect in these compound constructions consists in the difficulty of making the two kinds of iron act fully together in bearing the load. "The strength of cast-iron depends upon its rigidity; for, although it possesses the property of elasticity, this cannot be tasked with safety; and it is well known that repeated deflections will often destroy a casting which has withstood previous pressures with apparent impunity. Malleable-iron, on the other hand, applied in the form of truss-bars to cast-iron girders, is intended to act by the application of its tensile strength; but the effect of this can only be secured when it becomes active *before* the cast-iron girder has suffered any dangerous deflection. It is therefore indispensable that the adjustment of the length of the bars during all changes of temperature shall be strictly preserved,—a condition which is physically impracticable by any known form of construction or arrangement of parts." This defect was fatally illustrated by the failure of the largest bridge of this kind, erected over the Dee, near Chester, on the line of the Chester and Holyhead Railway. On the 24th May, 1847, one of the girders gave way, and the cause of the failure was variously ascribed to a passing train having got off the rails, and to an undue loading of the bridge with additional ballasting.

The first attempts to substitute wrought-iron for cast-iron in the construction of girders were made by joining plates of rolled-iron vertically with rivets, and attaching a strip of angle-iron on each side, both at top and bottom, so as to form artificial flanges, to give the required strength at those parts. Girders thus formed are said to have been applied by Messrs. Fairbairn in the construction of floors, in 1832, and they have been used as deck-beams in ships. Such girders were found liable to yield by twisting or bending laterally; and to obviate this defect, as well as to obtain the great strength and rigidity required in the employment of wrought-iron girders for railway constructions, the tubular form was designed, and T-iron used in forming vertical ribs, so that the side plates might be arranged vertically. Wrought-iron thus applied having been proved by experiment to have less power to resist compression than extension, it was desirable to increase the strength of the upper part of girders constructed of this material, and a separate compartment or cell was formed to obtain this object. These improvements were made by Mr. W. Fairbairn, and patented, October 8, 1846. The girders are formed of plates of metal, united by rivets and ribs of rolled-iron: the side plates are put together with but-joints, covered on the outside with stiles, or covering-plates, and on the inside with vertical ribs of angle or T-iron, the side plates, stiles, and ribs being riveted together. The top of this hollow beam is formed with two or more rectangular cells, composed of plates arranged vertically, and connected by strips of angle-iron and rivets with the top and side plates. The bottom is formed of iron plates, connected together by covering-plates over the cross-joints, and attached to the side plates by angle-iron and rivets. The top may be constructed either of cast or of malleable iron, and cellular, rectangular, or of an elliptical or any other form, to prevent the top puckering from compression; or other methods may be employed, such as thick metallic castings, or lighter iron plates, arranged so as to form hollow cells. The bottom may also be constructed of a series of plates, either of single or double thickness, riveted together. The joints of the plates alternate or break with each other, and are riveted by a peculiar method which the inventor calls *chain-riveting*, as it forms a chain of plates throughout; and the structure so unites the covering-plates as not to weaken the plates by rows of transverse rivet-holes, but to form a connecting link to each joint by a series of longitudinal rivets or pins. "This useful invention," says Mr. Dempsey, "which comprises the best methods yet devised for uniting the several parts of structures of plate and bar iron, contains also the essential principles upon which tubular girders may be, and have been, constructed, of a size adequate to form bridges within themselves, and admit the interior passage of railway trains or other traffic."

The first wrought-iron tubular girder bridge built under this patent, was over the Leeds and Liverpool Canal, for the purpose of carrying the Blackburn and Bolton Railway. Fig. 333 is an elevation, and Fig. 334 a transverse section of this bridge: Fig. 335 is an enlarged transverse section of one of the outer girders, and Fig. 336 an enlarged longitudinal view of part of one of the girders, showing a section of one of the cross timbers on which the railway is supported. The span of this bridge is 60 feet, and each girder is 66 feet in total length, the bearings of the masonry being each 3 feet long. The two lines of rails are carried between three parallel girders, G, each of which consists of a

(1) "Tubular and other Iron Girder Bridges," &c. By G. Drysdale Dempsey, C.E. This valuable little volume, forming one of the numbers of Mr. Weale's Rudimentary Series, has been of great assistance in the preparation of this Section.

rectangular top compartment, c, composed of plates $\frac{3}{8}$ inch thick, and riveted at the internal corners to

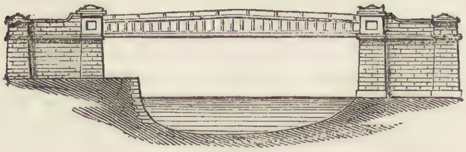


Fig. 333.

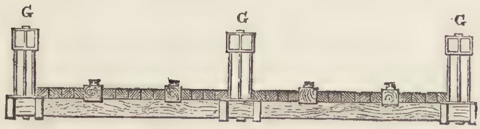


Fig. 334.

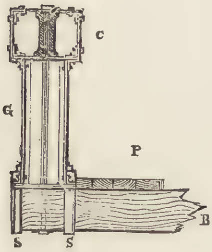


Fig. 335.

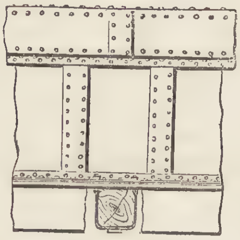


Fig. 336.

angle-iron; of side plates $\frac{5}{16}$ inch thick, joined vertically by rivets to T-iron ribs, and also riveted to the bottom plate of the top compartment, and its internal angle-irons, through longitudinal ribs of angle-iron placed externally; and of double bottom plates, each $\frac{3}{8}$ inch thick, joined by rivets to external longitudinal strips of angle-iron. The rails are laid upon longitudinal timbers, which, with intermediate planking, are supported upon transverse beams of wood suspended by double straps of wrought-iron, which pass upwards through the bottom plates of the girders, and are secured by screw nuts. A vertical bolt of wrought-iron also passes through a cast-iron socket in the top compartment of the girder, and downward through each cross-beam, below which it is fixed with a washer-plate and screwed nut. This structure on being tried by severe tests was found equal to any weight to which it could be subjected. Three locomotives, each weighing 20 tons, occupying the entire span of 60 feet, were run together as a train, at rates varying from 5 to 25 miles an hour, and produced a deflection in the centre of the bridge of only .025 of a foot. Two wedges of the height of 1 inch were then placed on the rails in the middle of the span, and the dropping of the engines from this height, when at a speed of 8 or 10 miles per hour, caused a deflection of only .035 of a foot, which was increased to .045 of a foot, or nearly half an inch only, when wedges $1\frac{1}{2}$ inch in thickness were substituted. A bridge of this kind of 60 feet span, containing 30 tons weight of iron, cost only 900*l.*; whereas a cast-iron trussed girder bridge of the same, required 76 tons of cast-iron, and 14 tons of wrought-iron, and cost 1,432*l.* 16*s.*

Malleable-iron has also been applied in various other forms of combination to the construction of bridges. The Patent Iron Bridge suggested by Mr. George Smart in 1824, consisting of a combination of wrought-iron bars, arranged in a diagonal form, is the parent of the numerous *lattice-bridges* so common in America. These present a vertical framing perfectly horizontal on its upper and lower lines, and composed of iron bars crossing each other in a diagonal direction, forming angles of about 18° with the horizon. (Fig. 337.) The framing also comprises vertical or *hanging-bars*, and *base*-bars forming the lower horizontal lines of the framing, and also passing horizontally over each alternate row of intersections of the diagonal bars. Each bar is forged of enlarged width at the points of intersection, through which bolts are fixed to connect the whole together. Two of these trussed frames erected vertically and parallel to each other form the supports of the roadway to be formed between them, the two frames being tied together by transverse connecting rods, the roadway or flooring being situated near the top of the frames, and never on the lower bars, which Mr. Smart regarded as an erroneous practice in wooden bridges. Between the frames, cross-braces, consisting of two light bars, are fixed, bolted together and fitted to the connecting rods. A lattice bridge of wrought-iron erected across the line of the Dublin and Drogheda Railway is 84 feet in clear span. Fig. 337 is a portion of a lattice bridge erected by Mr. Osborne on the Waterford and Limerick Railway.

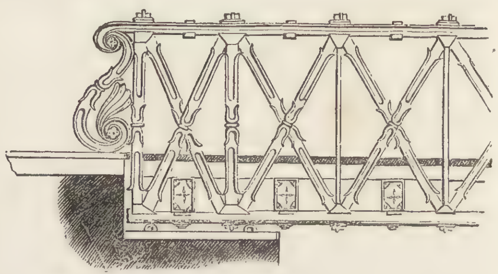


Fig. 337.

Mr. Dempsey points out an important distinction between the simple lattice or diagonal framing, and the roof framing. In the former, the strength is obtained by the connexion of the bars at each intersection, while the abutting principle of the roof is disregarded. The strain is therefore borne wholly by the rivets or pins which pass through the crossing bars, and the effect of this strain is shown in the gradual loosening of the pins. The bars are also considerably weakened by the holes through the middle of them, and in wooden lattice bridges, fracture and failure of the material have often resulted. The lattice principle has been considerably improved upon by Mr. R. B. Osborne, C. E., by the introduction of a top and bottom chord of malleable-iron with intermediate braces of cast-iron in the form of rectangular tubes.

For other forms and applications of tubular beams and girders, we must refer to Mr. Dempsey's work, and pass on to notice the grand application of the hollow girder or tube in the Conway and Britannia

Bridges, on the line of railway from Chester to Holyhead. The first of these tubular bridges was required for carrying the railway over the river Conway, and at about 18 miles further on, the separation of the Island of Anglesea from the main land of Caernarvonshire by the straits of Menai, gave occasion for the bolder structure of which the central pier is skilfully based on a rock, termed the Britannia Rock, from which the bridge derives its name.

It was the original intention of Mr. Robert Stephenson, the engineer of the works, to have crossed the straits with a cast-iron arched bridge, in two spans of 450 feet each, the height of the arches to be 100 feet from the level of the water to the crown of the arch, and the springing 50 feet from the level. As it was necessary that the water-way should not be interrupted by scaffolding or centering, it was proposed to fix the half-arches in each side of the central pier in portions simultaneously, and connect them with tie-rods, so that the weight on either side should balance that on the other.

This design for an arched bridge was frustrated by a condition insisted on by the Lords Commissioners of the Admiralty, as conservators of the navigation: viz. that the clear height of water-way under the lowest part of the arches, or their springing, should not be less than 105 feet. To have complied with this condition, the whole structure must have been raised 50 feet above the proposed position, thereby involving an immense additional cost in the piers and abutments, besides being irreconcilable to the adjoining levels of the railway. The engineer, therefore, abandoned the arched form altogether, and "conceived the original idea of a huge tubular bridge, to be constructed of riveted plates of wrought-iron, and supported by chains, and of such dimensions as to allow of the passage of locomotive engines and railway trains through the interior of it." In April, 1845, Mr. Stephenson obtained the assistance of Mr. William Fairbairn in carrying out his scheme. The first idea seemed to be, that the tube should be either of a circular or an egg-shaped sectional form, and that it should act by its rigidity and weight as a stiffener, and prevent, or, at least to some extent, counteract, the undulations due to the catenary principle of construction. Mr. Fairbairn appears from the first to have been opposed to the application of chains, even as an auxiliary. "I always felt that, in a combination of two bodies, the one of a perfectly rigid, and the other of a flexible nature, there was a principle of weakness; for the vibrations to which the one would be subjected would call into operation forces whose constant action upon the rivets and fastenings of the other could not but tend to loosen them, and thus, by a slow, but sure agency, to break up the bridge." [1]

But Mr. Stephenson wisely determined that these and all other points should be submitted to the test of an elaborate experimental inquiry, to determine, *first*, the peculiar sectional form which should be given to the tubes, and, *secondly*, the distribution and dimensions of the material which would ensure the required strength and rigidity of the entire structure. These experiments were conducted by Mr. William Fairbairn, assisted at a later period, dating from the 19th September, 1845, by Mr. Eaton Hodgkinson; the details and results of which were reported to Mr. Stephenson, who appended them to his own report, presented to the directors of the railway company in February 1846. An account of these experiments is given in Mr. Fairbairn's work, and an abstract of them is given in Mr. Dempsey's little volume. Experiments were made on the strength of iron tubes of various forms: Mr. Fairbairn's object being first directed to test the principle, originally suggested by Mr. Stephenson, of a structure every part of which, although rigid, should be brought into a state of tension, and whose strength should consist not as that of a beam or girder does in its resistance to extension on the one side and to compression on the other, but in a resistance to extension on both sides. It was found in the early experiments that the weakness of the tube was in its upper surface, which yielded to compression before the under side was upon the point of yielding to extension. Experiments were then made with a view to strengthen the upper surface, so that it should not be on the point of yielding to compression until the under surface was about to yield by extension. "This state of the tube was a necessary condition to the greatest economy of its material, for in any state in which it was not on the point of yielding on the one side at the instant when it was on the point of yielding on the other, some of the material might be taken from the stronger side without causing that to yield and added to the weaker so as to prevent that side from yielding, and thus the tube would be rendered stronger by a new distribution of its material. It was with reference to this principle that the rectangular form of section had suggested itself to me, in the place of the circular or the elliptical forms proposed by Mr. Stephenson, and that I had ordered the top of the tube to be thickened. It now occurred to me that the top might be strengthened more effectually by other means than by thickening it, and I directed two additional tubes to be constructed, the one rectangular, and the other elliptical, with hollow triangular cells or *fins* to prevent crushing. These experiments led to the trial of the rectangular form of tube with a corrugated top, the superior strength of which decided me to adopt that cellular structure of the top of the tube which ultimately merged in a single row of rectangular cells. It is this cellular structure which gives to the bridges now standing across the Conway Straits their principal element of strength."

On the 9th February, 1846, Mr. Stephenson made his Report to the Directors of the Chester and Holyhead Railway, in which he gives a summary of Messrs. Fairbairn and Hodgkinson's experiments. "The first series of experiments," he says, "was made with plain circular tubes, the second with

(1) "Conway and Britannia Tubular Bridges." By William Fairbairn C E. London 1849.

elliptical, and the third with rectangular. In the whole of these, this remarkable and unexpected fact was brought to light,—viz. that in such tubes the power of wrought-iron to resist compression was much less than its power to resist tension,—being exactly the reverse of that which holds with cast-iron: for example, in cast-iron beams for sustaining weight, the proper form is to dispose of the greater portion of the material at the bottom side of the beam,—whereas with wrought-iron these experiments demonstrate beyond any doubt, that the greater portion of the material should be distributed on the upper side of the beam. We have arrived therefore at a fact having a most important bearing upon the construction of the tube; viz. that rigidity and strength are best obtained by throwing the greatest thickness of material into the upper side. Another instructive lesson which the experiments have disclosed is, that the rectangular tube is by far the strongest, and that the circular and elliptical should be discarded altogether. This result is extremely fortunate, as it greatly facilitates the mechanical arrangements for not merely the construction, but the permanent maintenance of the bridge."

Appended to Mr. Stephenson's Report are separate Reports, the one by Mr. Fairbairn and the other by Mr. Hodgkinson. Mr. Fairbairn remarks that "with tubes of a rectangular shape, having the top side about double the thickness of the bottom, and the sides only half the thickness of the bottom, or one fourth the thickness of the top, nearly double the strength was obtained. In experiment 14, a tube of the rectangular form, $9\frac{1}{2}$ inches square, with top and bottom plates of equal thickness, the breaking weight was . . . . 3,738 lbs.

Riveting a stronger plate on the top side, the strength was increased to	8,273 lbs.
The difference being . .	4,535 lbs.;

considerably more than double the strength sustained by the tube when the top and bottom sides were equal. The experiments given in No. 15 are of the same character, where the top plate is as near as possible double the thickness of the bottom. In these experiments the tube was first crippled by doubling up the thin plate on the top side, which was done with a weight of . . . . 3,788 lbs.

It was then reversed with the thick side upwards, and by this change the breaking weight was increased to	7,148 lbs.
Making a difference of .	3,360 lbs.;

or an increase of nearly double the strength, by the simple operation of reversing the tube, and turning it upside down.

"The same degree of importance is attached to a similar form when the depth in the middle is double the width of the tube. From the experiment (No. 16) we deduce the same results in a tube where the depth is $18\frac{1}{4}$ and the breadth $9\frac{1}{4}$ inches. Loading this tube with 6,812 lbs. (the thin plate being uppermost,) it follows precisely the same law as before, and becomes wrinkled with a hummock rising on the top side, so as to render it no longer safe to sustain the load. Take, however, the same tube and reverse it with the thick plate upwards, and you not only straighten the part previously injured, but you increase the resisting power from 6,812 lbs. to 12,188 lbs. Let us now examine the tube in the 29th experiment, where the top is composed of corrugated iron, forming two tubular cavities extending longitudinally along its upper side. This, it will be observed, presents the best form for resisting the *puckering* or crushing force, which on almost every occasion was present in the previous experiments. Having loaded the tube with increasing weights, it ultimately gave way by tearing the sides from the top and bottom plates, at nearly one and the same instant after the last weight, 22,469 lbs. was laid on. The greatly increased strength indicated by this form of tube is highly satisfactory; and provided these facts be duly appreciated in the construction of the bridge, they will, I have no doubt, lead to the balance of the two resisting forces of tension and compression."

Referring to the suspension-chains which had been proposed as an additional element of security in the bridge, Mr. Fairbairn remarks, that "although suspension-chains may be useful in the construction, in the first instance, they would nevertheless be highly improper to depend upon as the principal support of the bridge. Under every circumstance, I am of opinion that the tubes should be made sufficiently strong to sustain, not only their own weight, but, in addition to that load, 2,000 tons equally distributed over the surface of the platform; a load ten times greater than they will ever be called upon to support. In fact, it should be a huge sheet-iron hollow girder, of sufficient strength and stiffness to sustain these weights; and, provided the parts are well proportioned, and the plates properly riveted, you may strip off the chains, and leave it as a useful monument of the enterprise and energy of the age in which it was constructed."

In the Table at the top of the next page, some of the data and the results of experiments upon rectangular tubes are brought together.

When the course of these experiments had indicated the form of tube which must actually be employed for the bridge, a model tube was constructed, as nearly as possible one-sixth the dimensions of the proposed tubes across the Menai Straits. The apparatus used for experimenting upon it is shown in Figs. 338 and 339. Fig. 339 represents at A a side-view, 75 feet between the supports; B is the platform supporting the weights, suspended from two cross-bars passing through the sides, and resting upon the outside angle-iron and the bottom of the tube, as shown in Fig. 338 at *a a*. C C is a balk of timber, passing under the cross-links *b b*, which, on being raised by two powerful screw-jacks *e e*, lifted the load from off the tube, in order to ascertain the effects of the successive loads upon the elastic powers of the tube. The temporary supports D D were only used

Experiments. Class.	No.	Length of Tubes between the Supports. Feet.	In.	Depth. In.	Width. In.	Area of Transverse Section. In.	Thickness of Plates. Top. In.	Bottom. In.	Ultimate Deflection. In.	Breaking Weight. lbs.	Manner of yielding.
H.	15	17	6	9.6	9.6	92.16	.075	.075	1.10	3,738	By compression.
	16						.272	.075	1.13	8,273	By extension.
	17						.075	.142	0.94	3,788	By compression.
	18						.142	.075	1.88	7,148	By extension.
I.	19	17	6	18.25	9.25	168.81	.059	.149	0.93	6,812	By compression.
	20						.149	.059	1.73	12,188	Ditto.
	21	18	0	13.25	7.50	99.37	.142	.142	1.71	13,680	Ditto.
	22	24	0	15.00	9.25	138.75	.160	.160	2.66	17,600	Ditto.
K.	23	18	6	13.00	8.00	104.00	.066	.066	1.19	8,812	Ditto.
	24	19	0	15.40	7.75	119.35	.230	.180	1.59	22,469	Sides distorted.

for the purpose of receiving part of the falling load, in case of accident or the rupture of the tube. It

Fig. 338.

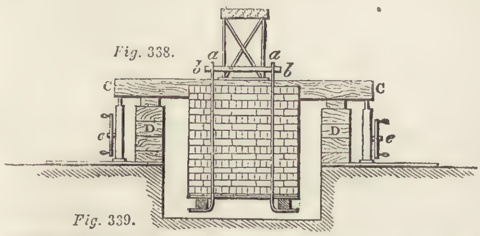
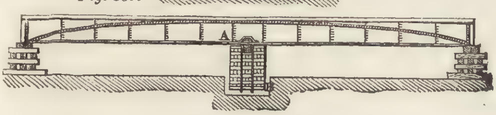


Fig. 339.



broke after sustaining a load of 79,578 lbs. a minute and a half, the bottom plate tearing asunder two feet from the centre of the shackle.

All these experimental trials were conducted by hanging a dead weight to the tubes under trial. The mechanical effect of such a weight is much less injurious than a weight passing over or through it with greater or less velocity, as in the case of a railway train. The commissioners appointed by her Majesty's Commission, of the 27th August, 1848, to inquire into the conditions to be observed by engineers in the application of iron to structures exposed to violent concussions and vibration, &c., investigated this subject experimentally. They constructed an apparatus by means of which a loaded car was allowed to run down an inclined plane: the iron bars which were the subject of the experiment were fixed horizontally at the bottom of the plane, in such a manner that the loaded car would pass over them with the velocity acquired in its descent. Thus, the effects of giving different velocities to the loaded car, in depressing or fracturing the bars, could be observed, and compared with the effects of the same loads, placed at rest upon the bars. Thus, for example, when the carriage, loaded to 1,120 lbs., was placed at rest upon a pair of cast-iron bars, 9 feet long, 4 inches broad, and $1\frac{1}{2}$ inch deep, it produced a deflection of $\frac{6}{10}$ths of an inch; but when the carriage was caused to pass over the bars at the rate of 10 miles an hour, the deflection was increased to $\frac{8}{10}$ths, and went on increasing as the velocity was increased; so that, at 30 miles per hour, the deflection became $1\frac{1}{2}$ inch; that is, more than double the statical deflection. "Since the velocity so greatly increases the effect of a given load in deflecting the bars, it follows, that a much less load will break the bar when it passes over it than when it is placed at rest upon it; and accordingly, in the example above selected, a weight of 4,150 lbs. is required to break the bars, if applied at rest upon their centres; but a weight of 1,778 lbs. is sufficient to produce fracture, if passed over them at the rate of 30 miles an hour. It also appeared that, when motion was given to the load, the points of greatest deflection, and, still more, of the greatest strains, did not remain in the centre of the bars, but were removed nearer to the remote extremity of the bar. The bars, when broken by a travelling load, were always fractured at points beyond their centres, and often broken into four or five pieces, thus indicating the great and unusual strains they had been subjected to." [1]

Engineers have generally supposed that the deflection caused by passing a weight at a high velocity over a girder is less than the deflection which would be produced by the same weight at rest; and even when they have observed an increase, they have attributed it solely to the jerks of the engine or train, produced by passing over inequalities at the junction of the rails, or other similar causes. For the purpose of examining this question, the commissioners submitted two actual bridges to the test of experiment. One was the Ewell Bridge, on the Croydon and Epsom line, and the other the Godstone Bridge, upon the South-Eastern line, both constructed to carry the railway over a road. "A scaffold was constructed, which rested on the road, and was therefore unaffected by the motion of the bridge, and a pencil was fixed to the under side of one of the girders of the bridge, so that when the latter was deflected by the weight of the engine or train, either placed at rest or passing over it, the pencil traced the extent of the deflection upon a drawing-board attached to the scaffold. An engine and tender were made to traverse the bridges at different velocities, or to rest upon them, at pleasure. The span of the Ewell Bridge is 48 feet, and the statical deflection due to the above load rather more than $\frac{1}{5}$th of an inch. This

(1) "Report of the Commissioners appointed to inquire into the application of Iron to Railway Structures." 2 vols. folio. 1850.

was slightly but decidedly increased when the engine was made to pass over the bridge; and, at a velocity of 50 miles per hour, an increase of $\frac{1}{7}$th was observed. As it is known that the strain upon a girder is nearly proportional to the deflection, it must be inferred, that, in this case, the velocity of the load enabled it to exercise the same pressure as if it had been increased by $\frac{1}{7}$th, and placed at rest upon the centre of the bridge. The weight of the engine and tender was 39 tons, and the velocity enabled it to exercise a pressure upon the girder equal to a weight of about 45 tons. Similar results were obtained from the Godstone Bridge."

With respect to the best qualities and mixtures of iron for girders, it appears that engineers have no guarantee that the mixture for which they have stipulated in a contract shall be that used by the founder, and no certain test by which to determine whether a given piece of iron has been manufactured by hot blast or cold blast. Mr. Fox recommends, as a good protection, "that engineers, in contracting for a number of girders, should stipulate that they should not break with less than a certain weight, (leaving the mixture to the founder,) and cause one more than the required number to be cast. The engineer may then select one to be broken, and, if it break with less weight than that agreed upon, the whole may be rejected."

The details which are now about to be given will refer chiefly to the construction of the Britannia Bridge. The Conway Bridge was erected within a few feet of Telford's suspension bridge, and close beneath the walls of Conway Castle. It consists of one span only, of 400 feet clear width, and two abutments of masonry, of which the design is in harmony with that of the castle.

The site selected by Mr. Stephenson for carrying his tubular bridge over the Menai Straits was determined by a mass of rock, occupying the centre of the stream, and of suitable dimensions to serve as the foundation of a central pier, and standing considerably above the level of low water. The distance of this rock, and of the bridge now built over it, from the great suspension bridge of Telford, is one mile lower down the straits, or in a southern direction. On the Caernarvon side, the shore rises abruptly from the water's edge, and shelves upward with a gentle inclination; so that a horizontal line passing at an elevation of 100 feet over the water, is, when extended about 400 feet inland from the water-line, only a few feet above the natural surface of the ground. On the Anglesea side, the rocky surface extends for a considerable distance, and, at a length of about 250 feet from the water-line, the surface is from 80 to 90 feet below the horizontal line just described. Hence, the embankment required to continue the railway from the Anglesea end of the bridge is much higher and more extended than that at the Caernarvon end. The Britannia Rock, which rises from near the middle of the bed of the strait, is covered at high water to a depth of 10 feet, and stands at low water about 10 feet above it. A tower of masonry is erected on this rock, and at the clear distance of 460 feet from it, at the limits of the water-way, another tower is built on either side of it, Fig. 340. At the distance of 230 feet

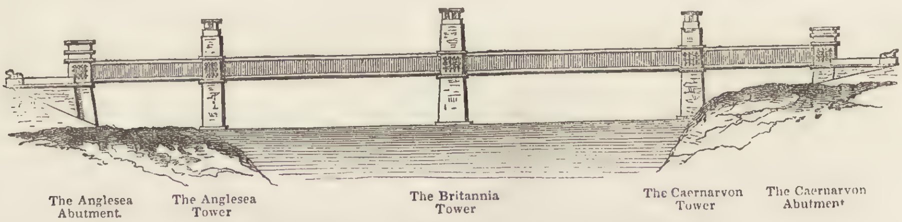


Fig. 340. ELEVATION OF THE BRITANNIA TUBULAR BRIDGE.

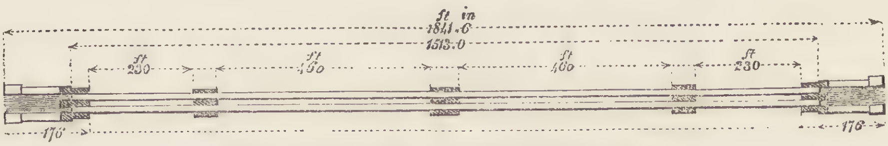


Fig. 341. PLAN OF THE BRITANNIA TUBULAR BRIDGE.

from each of these towers is a continuous abutment of masonry, 176 feet in length. The sides of these five stupendous masses of masonry are tapered with a straight batter. The Britannia tower is 62 feet by 52 feet 5 inches, at the base, and is reduced by the batter to 55 feet 5 inches at the height of 102 feet above high-water line, at which level the tubes pass through it. A plinth extends round the base of this and the other towers; and the height of this tower above high-water level is 200 feet, or nearly 230 feet from the bottom of the foundation on the rock. The stone used for the external parts of all the masonry is a hard and durable limestone, known as *Anglesea marble*. The interior of the masonry is a soft red sandstone, quarried at Runcorn, in Cheshire. The Britannia tower is constructed with hollow spaces or chambers within it. The total weight of the masonry in this tower is about 20,000 tons, and about 387 tons of cast-iron, in beams and girders, are built in it. The foundations were laid, and the work constructed up to the level of high-water, during the intervals of the tide. The stones in the whole of the masonry were left with the quarry or rough face, except at the angles, where they were dressed to a square arris, and in the recesses and top entablature, where they were dressed to a fair face all over. The Anglesea and

Caernarvon towers have the same dimensions at the base as the Britannia tower, but the height is 10 feet less. The abutments are 176 feet in length, and of a width corresponding to the towers, viz. 55 feet at the level of the bottom of the tubes. The continuations of the abutments are surmounted with parapet walls of solid masonry and of considerable height, each of which terminates at the extremity of the bridge with a projecting pedestal, on which a colossal couchant lion faces the approaching visitor. Each lion is composed of 11 pieces of limestone, and measures 25 feet in length and 12 feet in height, weighing about 30 tons. They were executed by Mr. Thomas.

The four spaces between the Britannia tower and the other towers, and between these and the abutments, had to be spanned by the iron tubes, and, as each tube serves for only one line of rails, 8 tubes were required, 4 of 460 feet, and 4 of 230 feet, the four longer ones being over the water, and the four shorter ones over the land. Thus it will be understood that each line of way through the bridge is composed of four separate tubes, united together, so that in the double line of railway there are two parallel tubes, each 1,513 feet long. To unite each of the four sections, short lengths of tube were constructed within the towers, which, being united with the main lengths, make up each complete and continuous tube. For the four shorter, or land tubes, scaffolds were erected, and the tubes constructed at once in their final position; but the four main tubes were constructed on timber platforms on the shore, and conveyed in flat-bottomed vessels, or *pontoons*, to the towers, where they were deposited, and raised to their required elevation of 102 feet above high-water level by means of hydraulic presses. In this way, all scaffolding across the straits was avoided, and the interruption of only half the channel at one time was limited to the brief period occupied in raising each tube from the base of the towers.

The site selected for the construction of the 4 main tubes was on the margin of the Caernarvon shore, to the south of the bridge. An intermediate space was occupied with workshops, &c., and cottages were built for the accommodation of about 500 workmen. Four strong stages were erected upon piles, and a continuous platform laid from end to end of the site, Fig. 342, consisting of timber posts and

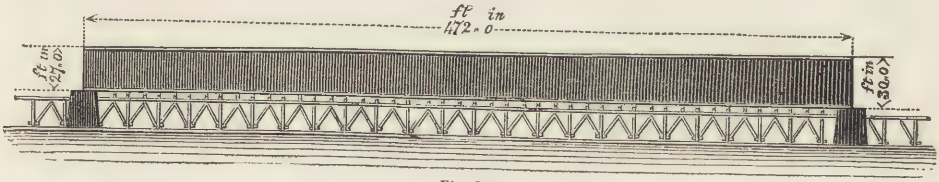


Fig. 342.

struts, with top stringers and beams, covered with stout planking. A pier of masonry was built at each end extending under each end of the tube for a length of 6 feet, so that when each tube was completed and the platform removed, the tube

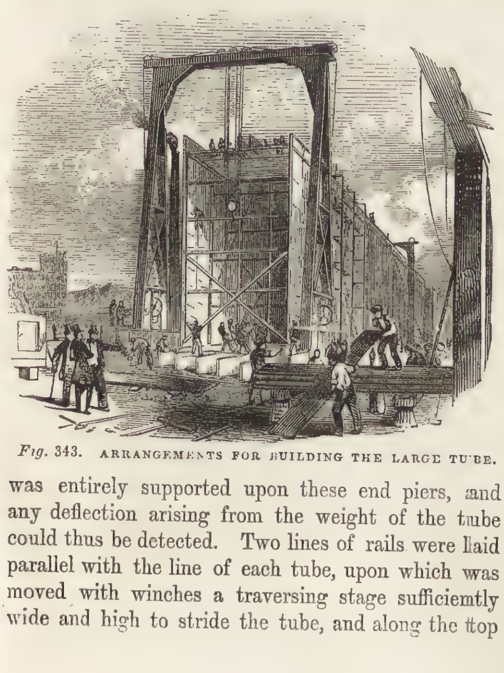


Fig. 343. ARRANGEMENTS FOR BUILDING THE LARGE TUBE.

was entirely supported upon these end piers, and any deflection arising from the weight of the tube could thus be detected. Two lines of rails were laid parallel with the line of each tube, upon which was moved with winches a traversing stage sufficiently wide and high to stride the tube, and along the top of it a small crab, Fig. 343, moving upon wheels, was made to traverse the width of the work, and was thus applied to raise the plates and materials. Portable furnaces accompanied the men employed in riveting.

Fig. 344, is a cross section of one of the tubes, showing the general form of construction: the sides are parallel, but the height is slightly varied. The height externally is 30 feet at the centre in the Britannia tower, and this is reduced to $22\frac{3}{4}$ feet at the extremities in the abutments, the bottom line being horizontal, but the top line forming a parabolic curve, the rise of which thus equals the difference in height, or 7 feet 3 inches. The clear internal height is 26 feet at the centre, and $18\frac{3}{4}$ feet at the ends. The external width is 14 feet 8 inches, and internally 14 feet, which is further reduced 7 inches by the ribs.

The covering of the tubes consists of malleable iron plates, connected together by rivets with ribs of T and L-iron, besides strips of flat bar-iron over the joints. The tubes are strengthened at top and bottom with internal longitudinal tubes or cells, of which there are 8 in the upper part and 6 in the lower. The plates vary in dimensions and thicknesses. The side plates are reduced in thickness from the ends towards the middle of the tube, and those forming the top and bottom are increased in the same direction. The side plates are alternately $6\frac{1}{2}$ feet and 8 feet 8 inches long, and all 2 feet wide. They are arranged vertically, so that the joints occur

at every 2 feet; they are $\frac{1}{2}$ inch thick in the middle of the length of the tube, and $\frac{5}{8}$ inch thick at the ends. The top plates are all 6 feet in length and $1\frac{3}{4}$ foot in width, and vary in thickness from $\frac{5}{8}$ inch

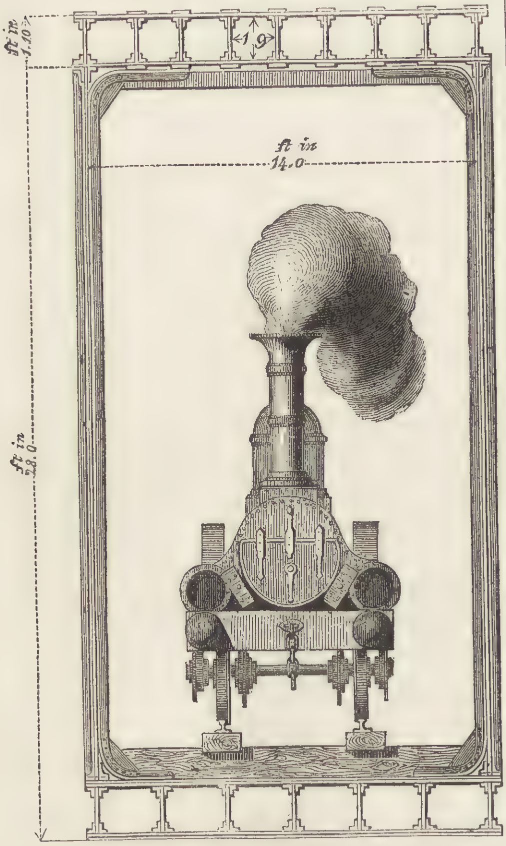


Fig. 344. CROSS SECTION OF ONE OF THE TUBES.

at the ends of the tube to $\frac{3}{4}$ inch in the middle. The bottom plates are 12 feet long and 2 feet 4 inches wide; they are in two layers, and the plates in each are $\frac{7}{16}$ inch thick at the ends of the tube, and $\frac{9}{16}$ inch thick in the middle of the main tubes. The difference in width of the top and bottom plates arises from the difference in the number of cells in the top and bottom of the tube, $1\frac{3}{4}$ foot being the width of each of the 8 top cells, and 2 feet 4 inches that of each of the 6 bottom cells. All the joints of the plates are *but-joints*, Fig. 350, or those which meet at the edges without overlapping. The horizontal joints at the ends of the plates are covered with plates of iron on both sides and firmly riveted through them. The side elevation Fig. 345, will explain this construction. Fig. 346 is a plan of part of the top of the tube, showing the joints in the plates alternating with each other and strengthened with covering plates.

The vertical frames upon which the plates are fixed are chiefly of T-iron. These ribs are bent at right angles at the ends, and extend for about 2 feet along the top and bottom plates of the principal compartments of the tube. The side plates meet with a but-joint over the centre of the rib, and a similar rib being placed on the outside in a re-

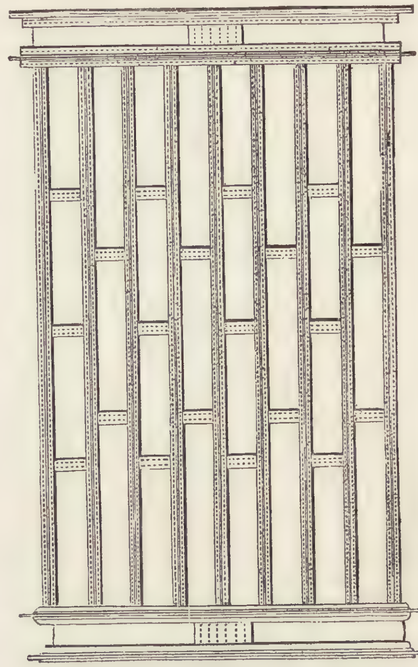


Fig. 345

versed position the whole are firmly riveted together. Where the tube passes through the towers, flat bar

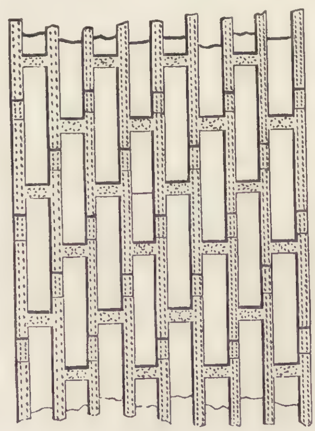


Fig. 346.

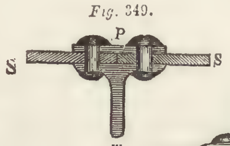
iron is substituted for the outside T-iron ribs. The vertical joints of the main tubes are strengthened for about 60 feet at each end by a strong plate 9 inches wide, passing at right angles between the edges of the plates, and every sixth rib throughout the entire length is strengthened with an additional plate inside, meeting the edge of the T-iron rib.

Figs. 347, 348 show the sections of T-iron and L-iron used for the ribs. The former T is 5 inches wide over the table and $3\frac{1}{2}$ inches deep; the latter L is $3\frac{1}{2}$ inches wide each way. Fig. 349, shows the kind of joint used in connecting the side plates SS of the tube within the towers; P is the outside covering

plate; and T the inside rib of T-iron. Fig. 350 shows the ordinary framing of the ribs and side plates: S S are the side plates of the tube; O R the outside and I R the inside ribs of T-iron. Fig. 352 represents the framing of 30 of the vertical joints at

Fig. 347

Fig. 349.



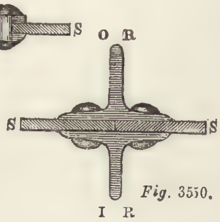


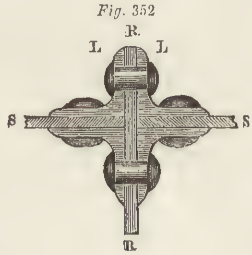
Fig. 350.

Fig. 348.

each end of the main tubes, showing the central plate against which the ends of the side plates are fitted with the 4 L-iron ribs in the angles, the whole of which are firmly riveted together. Fig. 353 shows

Fig. 351.

Fig. 352



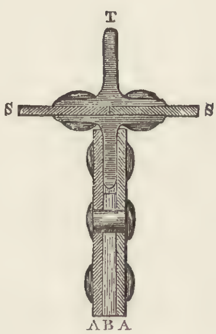


Fig. 353.

the framing adopted at every sixth of the vertical ribs, or every 12 feet distance throughout the main tubes. S S are the side plates of the tube; T the outside rib of T-iron; A A the flitches of plate iron; and B the filling-in plate, riveted between them. Fig. 351, is a perspective sketch of a portion of one of the ordinary vertical joints, showing a portion of two side plates meeting at the centre of the inside and outside ribs, and also the manner in which the joints of the T-iron ribs are strengthened with side pieces of L-iron and riveted through them.

The angles of the principal compartment of each tube are strengthened with *gussets*, or triangular plates of iron riveted through the ribs of T-iron. See Fig. 344. At every sixth rib the gussets are of larger dimensions, or about 5 feet in height and $1\frac{3}{4}$ foot in width.

The cells are formed with vertical partitions of plate-iron, connected at the angles with the upper and lower plates by horizontal ribs of L-iron fitted to the angles and firmly riveted. The top and bottom edges of the side plates of the tube are also riveted to the horizontal plates, forming the cells through ribs of L-iron in the angles.

The rails for the railway, Fig. 344, are supported in chairs upon continuous longitudinal timbers, which are supported upon pieces of L-iron, reversed so as to form brackets, and riveted through plates of iron 9 inches wide, set on edge and fixed across the tube at intervals, and secured to the vertical T-iron ribs, and the plates forming the top of the lower cells.

The rivets are about an inch in diameter, and arranged in rows, 3 inches apart in the vertical joints, and 4 inches in the horizontal. The rivets were heated in portable furnaces, and were taken up with tongs, and being placed in the holes punched for them, the ends were firmly clenched or riveted before cooling, with heavy hammers. The rivet-head thus formed was then finished by hammering a steel cup-shaped tool upon it, and the contraction of the length of the rivet in cooling, drew the plates closely together with considerable force. About 2,000,000 rivets were used in the entire work. The holes were punched in the plates by a beautiful machine invented by Mr. Roberts on the principle of the Jacquard loom. Large portions of the plating for the tubes were put together partially on the platforms, and being raised to their places by means of the stages and tackling, were speedily fixed in their true positions, and required only to be riveted to complete their connexions.

The tubes in passing through the towers and abutments were supported on rollers, a set of which is

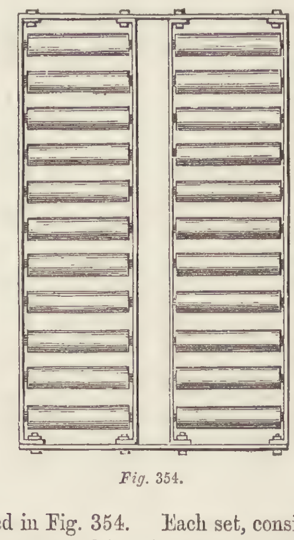


Fig. 354.

represented in Fig. 354. Each set, consisting of 22 rollers, was arranged in a frame in two parallel rows, the axes projecting through holes in the frame. One of these frames was placed under each side of each end of each tube, so that 32 sets of rollers and frames

were employed. The depth of the frame was less than the diameter of the rollers (which was 6 inches), so that it was not in contact with the cast-iron plates placed upon the rollers. This will be understood by referring to Fig. 362, which is a front view of these plates, *m m*, and of the intermediate rollers and frame. The under roller-plate rests in a bed of wood, and the upper roller plate, in which the tube rests, is thus free to move according to the expansion or contraction which it undergoes.

The ends of the tubes are further supported by an apparatus of cast-iron girders and balls of gun-metal applied in the following manner:—longitudinal girders are attached to the projecting ends of cross girders built in the walls of the towers: these longitudinal girders are formed with a groove or channel in the upper surface, in which the gun-metal spheres 6 inches in diameter are free to move. Similar girders are placed over these, with a corresponding groove on their under side, and thus free to move over the spheres. Upon these upper girders, transverse girders are fixed, which pass over the tube and are fixed to it with strong bolts 3 inches in diameter, which stand up vertically above the tube, bolted to its side, and, passing through holes cast in the transverse girders, are secured to them with screwed nuts. The ends of the tubes in the towers are stiffened with cast-iron frames of considerable dimensions.

The following is the weight of a single line, and the number of rivets, together with the sectional areas at the centre of the large tubes:—

	Tons.	Sectional Area.	Number of Rivets.
Top	1,481	648.25 sq. in.	310,390
Sides	1,727	302.00	535,650
Bottom	1,472	585.43	249,010
	4,680	1535.68	1,095,050

The floating of the main tubes from the building stage to the base of the towers required much previous arrangement. As each tube was completed, it was left to bear upon the piers of masonry at its ends, the staging below being removed. For the purpose of transporting each tube, eight flat-bottomed floating vessels or pontoons were provided, six of wood and two of iron, the latter being 98 feet long, 25 feet wide, and 11 feet deep, and capable of supporting 400 tons. When bearing the tube, they drew 5 feet of water. In the bottom of each pontoon were large valves, kept open to admit the tide and prevent them from rising. The first operation for floating the tube was to bring these pontoons under it at low water, and to arrange them in two groups of four each, one group near each end of the tube. The valves being then closed, the pontoons rose with the tide and lifted the tube from its bearings. The next operation was to tow and guide this enormous floating body to the exact spot required for depositing it. Calculating that the towing would occupy an hour and a half, it was arranged to start thus much before high water, and with a current of 3 miles an hour. The towing into the middle of the stream was effected by means of large capstans, each worked by 50 men on the opposite shore, the hawsers being made fast to the pontoons at each end. For the purpose of guiding it, two large hawsers were laid down the stream, one on either side, one end being secured to the towers between which the tube was to be raised, and the other to fixed points upon the shore about half a mile from the bridge. These hawsers passed over the pontoons and through fixed sockets in an apparatus called a *cable-stopper*, by which either hawser could be instantly gripped if necessary, so as to stop the motion of the tube. Several smaller ropes were also secured to the pontoons, so arranged as to be taken in or given out by capstans on the shore.

The tube being conveyed to the feet of the towers at high water, the next work was to deposit it on the projecting plinths of the towers which had been prepared for the purpose. This had to be accomplished during the 15 minutes that the tide ceases before the return. Fig. 355 represents the lower part of the

Fig. 355.

Anglesea and Britannia towers A and B, at this period; T is the tube supported upon the eight pontoons and ready to be deposited upon the projecting plinths of the towers. One end of the tube is shown in dotted lines as inserted within the recess left in the Britannia tower, and in the Anglesea tower a portion of the masonry is left out, forming the side of the recess of sufficient height to admit the tube. A sectional plan of the two towers A and B is given in Fig. 356. The

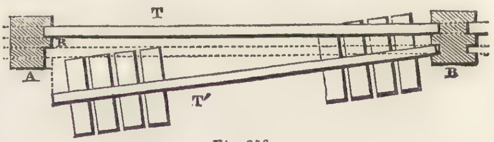


Fig. 356.

former had two recesses on one side for receiving the main tubes, and the latter similar recesses on both sides for the same purpose. One tube T is shown in its place, and the side of the recess at R built up: the other, T′, is still on the pontoons, one end being in the recess of the Britannia tower, and the other end approaching its place in the Anglesea tower, the side of the recess in which, shown in dotted lines, is left unbuilt to receive it. Fig. 357 is a perspective view of the lower part of the Anglesea tower after the raising of one tube and during the raising of the other. It shows the mode of getting the tubes into the recesses by leaving out a portion of the sides at the lower part.

The proceedings connected with the floating of one of the main-tubes on the 27th June, 1849, are described by a correspondent of the Illustrated London News. After the preliminary arrangements for letting go had been completed, Mr. Stephenson and other engineers got on the tube, as also Captain Claxton, R. N., to whom the management of the floating was

entrusted. "Captain Claxton was easily distinguished by his speaking-trumpet, and there were also men to hold the letters which indicated the different capstans, so that no mistake could occur as to which capstan

Fig. 357.

should be worked; and flags, red, blue or white, signalled what particular movement should be made with each. About 7.30 P. M. the first perceptible motion, which indicated that the tide was lifting the mass, was observed, and, at Mr. Stephenson's desire, the depth of water was ascertained and the exact time noted. In a few minutes the motion was plainly visible, the tube being fairly moved forward some inches. This moment was one of intense interest; the huge bulk gliding as gently and easily forward as if she had been but a small boat. The spectators seemed spell-bound; for no shouts or exclamations were heard, as all watched silently the silent course of the heavily-freighted pontoons. The only sounds heard were the shouts from Captain Claxton, as he gave directions to 'let go ropes,' to 'haul in faster,' &c. and 'broadside on:' the tube floated majestically in the centre of the stream. I then left my station and ran to the entrance of the works, where I got into a boat and bade the men pull out as far as they could into the middle of the straits. This was no easy task, the tide running strong: but it afforded me several splendid views of the floating mass, and one was especially fine: the tube coming direct on down the stream,—the distant hills covered with trees,—two or three small vessels and a steamer, its smoke blending well with the scene,—forming a capital background; whilst on one side, in long-stretching perspective stood the three unfinished tubes, destined ere long to form, with the one then speeding on its journey, one grand and unique roadway. It was impossible to see this imposing sight and not feel its singleness, if we may so speak. Anything so mighty of its kind had never been before: again it would assuredly be; but it was like the first voyage made by the first steam vessel,—something till then unique. At 8.35 the tube was nearing the Anglesea pier, and at this moment the expectation of the spectators was greatly increased, as the tube was so near its destination; and soon all fears were dispelled as the Anglesea end of the tube passed beyond the pier, and then the Britannia pier end neared its appointed spot and was instantly drawn back close to the pier, so as to rest on the bearing intended for it. There was then a pause for a few minutes while waiting for the tide to turn; and when that took place, the huge bulk floated gently into its place on the

Fig. 358. FLOATING THE MAIN TUBE

Anglesea pier, rested on the bearing there, and was instantly made fast so that it could not move again. The cheering, till now subdued, was loud and hearty, and some pieces of cannon on the shore gave token, by their loud booming, that the great task of the day was done." When in its position, the tube was made to settle down upon a bed of timber on its bearings at the foot of the towers, by opening the valves in the pontoons, and thus sinking them sufficiently to free them from the tube.

The tube, having been thus deposited at the bottom of the piers by the buoyant power of water, had to be raised through an elevation of 100 feet over a rapid stream of 460 feet in width, without scaffolding of any kind over the opening. The method proposed for effecting this was by means of hydrostatic presses of great power constructed for the occasion. The enormous force exerted by these presses well fitted them for raising the ponderous mass of 1,800 tons; but the range of the presses was but small, the ram being susceptible of only 6 feet vertical from the cylinder. Hence the tube had to be raised to the required height by a succession of lifts, each of 6 feet, and in order to bring the rams into action, they must either press upwards against the bottom of the tube, or being placed above it, be made to act upon chains, so as to draw them upwards, and with them the tube fixed to their lower ends. The latter course was adopted, and the presses were firmly fixed in the upper

part of the towers immediately over the ends of the tube, and at such a height as allowed the tubes to be entirely raised without disturbing the presses. The two presses used for raising the tubes for the Conway bridge, were used in combination at one end for raising the tubes of the Britannia bridge, and at the other end a single press of larger dimensions was employed. The ram of this press was 20 inches in diameter, and the metal of the cylinder 11 inches thick. For the purpose of forcing the water into the cylinders of these presses, two steam engines, each of 40-horse power, were employed. The actual work done by the large press at one end of the tube, or the two smaller ones at the other, is of course equal to raising half of the tube, or 900 tons: hence the power exerted by the head of the ram 20 inches in diameter, is equal to 2.25 tons or 5,040 lbs. per circular inch.

During the lifting of the first of the Britannia tubes on the 17th August, 1849, after three of the 6-feet lifts had been successfully accomplished on previous days, the lifting was proceeding and 2½ feet was attained, when the bottom of the cylinder of the large press burst out, and fell with terrible force (its weight being about 1½ ton) on the top of the tube below, a depth of 70 or 80 feet, producing a deep indentation, and unfortunately striking fatally a poor sailor employed on the works, who at the time was ascending a rope ladder from the tube to the press. The resistance to the weight being thus suddenly destroyed, the ram of course descended the part of the lift accomplished, and the tube would also have fallen through a similar space of 2½ feet, had not Mr. Stephenson adopted the wise precaution of following up the ascending tube with packings of wood 1 inch thick, which were introduced within the recess as quickly as the tube rose. This accident will sufficiently account for the considerable delay in raising the tube.

At the meeting of the British Association for the Advancement of Science, held at Birmingham in September 1849, Mr. Stephenson explained the cause of the accident. He stated that the plan originally proposed, was by lifting the tube to the height of 6 feet at a time, and then allowing it to be suspended by chains to the cross head during the time the masonry below was carried up: but this plan was abandoned, fearing that if an accident should take place either by the bursting of the press or the breaking of a link of the chain, the tube would be totally destroyed if it fell through such a height as 6 feet or even 6 inches. He considered that the only way to proceed was by packing in timbers inch by inch under the tube as it was being lifted, so that in case an accident did take place, the tube would not have to fall through a greater space than an inch, and this was the plan adopted at the time of the accident To show how necessary this was, it was stated that although the tube fell through the space of only 1 inch, it broke down iron beams, each sufficient to bear 500 tons weight. As a further precaution, it was intended to pack in under the cross-head of the press, by driving in iron wedges as the tube was raised, so that if the press were to break down, neither the cross-head nor the tube could fall through a greater space than an inch. The nature of the fracture will be seen from Fig. 359, and it is curious to find that the fracture took place at that part of the press which was the strongest, for it broke through the angle of the bottom at F, and when it fell out, the piece formed the frustum of a cone. At the time the presses were at work, there was not 1 ton pressure to the square inch, the area of the fracture being 1,316 square inches, and the weight suspended on the press 1,000 tons. The press was calculated to bear 3¼ tons, a pressure to which hydraulic presses are frequently subjected for manufacturing purposes. The ram at the time of the accident dropped 2½ feet: if it had been wedged up as now proposed, the accident might not have occurred. Mr. Stephenson believed the fracture took place in consequence of the unequal cooling of the iron at the angle F; he had therefore decided upon having two cylinders cast in some other form, one as in Fig. 360 with a spherical bottom, the same thickness as the

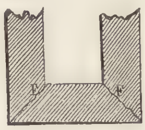


Fig. 359.

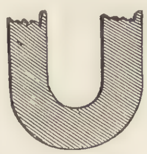


Fig. 360.

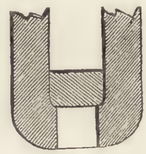


Fig. 361.

cylindrical part; and the other as in Fig. 361, with an open bottom and a plate made to close the opening. It was also stated that when lifting the Conway tubes, they commenced by lifting both ends simultaneously; but when the engines had been at work for a short period, the tube was observed in a tremulous motion like a wave. By working the pumps at each end alternately, the motion was got rid of. Some distinguished mechanical philosophers present at the meeting, considered that the accident at the Britannia bridge might have been occasioned through pulsation of the press, arising from the oscillating motion, however small, of the tube.[1]

A perspective view of the Anglesea tower is given in Fig. 357, showing one of the tubes elevated to its place, and another tube partly raised. It also shows the three cast-iron key-beams drawn out and supported on a bracket platform. When the tube was lifted to its full height, these beams were driven into their permanent places in the boxes which were built into the towers, and thus served to support the ends of the tube while the chains and lifting frames were detached. The rising tube had also a stage slung upon it, upon which the workmen were supported for the purpose of packing the wooden slabs under the tube as it rose, and building up the recess with brick-work in cement.

Figs. 362 and 363 show the combined arrangements for lifting the tubes of the Conway Bridge, with the hydraulic press, chains, &c. and the cast-iron lifting frames, as described in Mr. Fairbairn's work. Fig. 362 is a transverse section through the tube and front

(1) Civil Engineer and Architect's Journal for October 1849.

elevation of the press. Fig. 363 is a side view of the end of the tube, together with the press. In the sectional view it will be observed that the press H had to be supported upon 4 large cast-iron beams A 1, A 2. The two principal beams

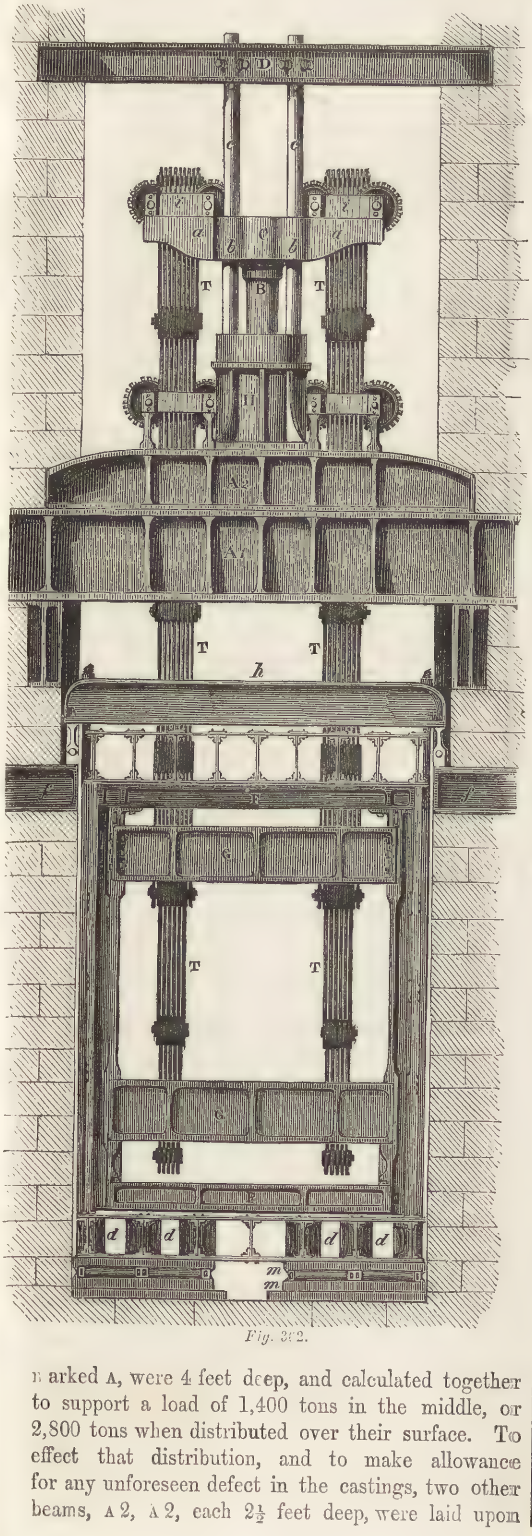


Fig. 362.

marked A, were 4 feet deep, and calculated together to support a load of 1,400 tons in the middle, or 2,800 tons when distributed over their surface. To effect that distribution, and to make allowance for any unforeseen defect in the castings, two other beams, A 2, A 2, each $2\frac{1}{2}$ feet deep, were laid upon the top of the beams A, and by means of a lining of soft wood between them, an equal distribution of load was obtained. On the top of the ram B was placed the cross-head C, having a perfectly flat surface on the top side, and two rectangular openings at each

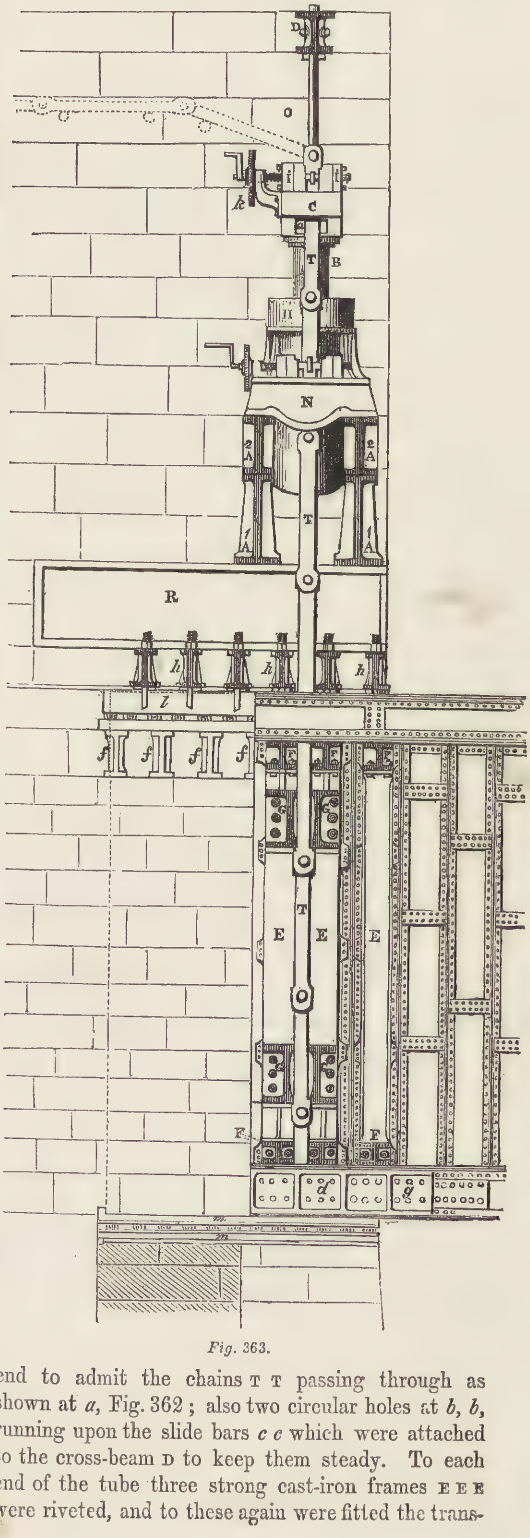


Fig. 363.

end to admit the chains T T passing through as shown at *a*, Fig. 362; also two circular holes at *b*, *b*, running upon the slide bars *c c* which were attached to the cross-beam D to keep them steady. To each end of the tube three strong cast-iron frames E E E were riveted, and to these again were fitted the trans-

verse beams F F F, &c., collectively forming three strong frames, of the height, width and interior dimensions of the end of the tube. The object of these frames was to stiffen the sides, top and bottom of the tube, and to connect them with each other at the point where it rested on the piers, and had to sustain a pressure of from 600 to 700 tons. These frames had also to receive the cross beams G G, to which the chains for raising the tubes were attached. These latter beams were computed to sustain a load of 3,000 tons and upwards, and the more effectually to equalize the pressure upon them, wrought-iron keys were inserted between the cross-beams and the shoulders of the side frames E E, which also had the effect of regulating and rendering uniform the tension of the chains. In this way a power was obtained of giving to each beam its equivalent share of the load.

The reasons for giving rigidity to each end of the tube were, 1st, to strengthen the sides at those parts, and to protect the upper and lower cells from injury; 2dly, to strengthen the lower cells and render them capable of sustaining the weight of the tube when resting wholly on its base; and 3dly, to make the whole of these parts of sufficient strength to resist the strain, whether arising from a vertical pressure upon the bottom, or from a tensile strain when suspended by the chains and hydraulic pumps. To attain these objects the strong cast-iron frames E E, &c., were inserted, which acted alike as pillars and suspenders, and the cross beams F F, &c., which distributed the pressure along the under and upper surface of the cells, thereby equalizing the strain in almost every direction over the interior as well as the exterior portion of that part of the tube.

The cast-iron frames *d, d, d,* &c., which embrace the vertical divisions of the lower cells, extend to a distance of 4 feet beyond the bearing of the tube, where they terminate on the sides of the plates, with a thin edge like a wedge, as at *g*, Fig. 363. By this arrangement a strong and perfectly rigid basement was introduced at the points of greatest pressure, without obstructing the entrance into the cells, or in any way impairing the efficiency of the tubes. In the upper cells, which are not subject to pressure, the same precautions were not required, since it was found that the top cross frames F were amply sufficient to protect these cells from injury during the process of lifting.

In addition to the two large beams A 1 and A 2 for supporting the hydraulic press, two strong beams B were built in the side walls, on each side of the recess, to prevent the unusual strain of such an enormous weight fracturing the masonry and sliding off in the shape of a wedge. Besides these beams, six other transverse beams were inserted at *ff*, &c., carrying the cast-iron troughs *ll*, &c. which held the gun-metal balls on which the upper part of the tube was supported. On the back or top of the upper troughs rested the ends of six strong cast-iron beams *hh*, &c. These beams crossed each end of the tube at a distance of 3 inches from the top, and by means of an equal number of screw-bolts riveted to the sides of the tube, the required weight could be thrown upon the balls. Thus the tube was not only supported by the top as well as the bottom, but one half of the weight resting upon the balls gave additional security to the vertical position of the tube when advancing to or retiring from the towers by the expansion or contraction of the metal. At the other end, which was stationary, the same principle of support was employed, except that the balls and rollers were not required. The bottom of the plate at the movable end was supported on the bed-plates *m m*, and between them were two frames containing drilled rollers, Fig. 354, on which the top plate, and along with it the tube, moved with the same facility as on the balls above.

The lifting chains T, T, were formed in links with notches at one end of each alternate link, fitting into corresponding ones on the lower flanges of the cross girders G G, and when these were bolted in their places, the links were as shown in Fig. 362, held firmly between them. Each set of links consisted of 8 and 9 alternately, the 8 being made somewhat thicker than the 9, so as to be equally strong. Each link was 7 inches wide, and about 1 inch thick, and exactly 6 feet in length between the centres of the eyes at the ends, their length being thus adjusted to the stroke of the ram of the press. They were manufactured by Howard's patent process, by which wrought-iron bars are rolled with the ends or heads of increased breadth in one entire piece, thereby getting rid of the uncertain process of welding.

The press by which these chains were drawn up, and the tube thereby raised, is shown in the place above the tube which it occupied during the whole operation. The press consists principally of the cylinder H, the ram or piston B, a pipe by which the water was introduced from the pumps, and the cross-head C. The cylinder rested within a cast-iron jacket or casing, supported upon the transverse girders A 1 A 2. The forcing of water into the cylinder causes the ram to rise, forcing up with it the cross-head C. Upon the cross-head two pairs of clamps, *i i*, were fixed, which embraced the notched ends of the chain links and were screwed up tightly against them with screws. These screws had cogged wheels *k* fitted to their ends, and an intermediate pinion, turned by a winch, gave motion to the wheels of the two screws. A similar arrangement of clamps and gearing was fixed below. The action of the press was preserved in a truly vertical direction by fixed guide rods, *c c*, secured above to the cross-girder D, and upon these rods the cross-head slid upward as the action of the press continued. The apparatus by which the tubes were sustained during the time of lowering the ram for the succeeding lift, consisted of two distinct sets of clips, one for embracing the links upon the cross-head of the ram during the time of lifting, as shown at C, and the other for supporting the weight of the tube on the frame N until the ram and cross-head were lowered to a position for seizing the next link. These changes were effected by the simple process of screwing the clips which slide

upon the cross-head c, close upon the chains, when the tube had to be raised; and by a similar movement of the clips which slide upon the frames N they were drawn under the shoulders of the links, and by this means the tube was held suspended until the clips on the cross-head were opened and the ram lowered for the succeeding lift. This was done by the wheels and pinions *kk*, which opened or closed the clips by right and left-hand screws, which, working in brass nuts, were attached to each block. The top links at O were dragged forward along the top of the tower during the ascent of the tube without disjointing the links.

In concluding this notice of the Britannia Tubular Bridge, it should be stated that the masonry of the Central or Britannia Tower was commenced in May, 1846; that the first rivet for the tubes was put in on the 10th August, 1847, and the last of the tubes was safely lowered to its permanent resting place on

Fig 364. MR. STEPHENSON PUTTING IN THE LAST RIVET.

Friday, the 3d September, 1850. The Caernarvonshire end of the tube was lowered three feet, the opposite end being joined on to the Anglesea large tube in the interior of the tower on the Britannia rock, and, obedient to the law of the novel operation, the centres of both tubes, as before, were raised up several inches. Nothing beyond a mere fractional deflection has been observed to take place in the tube that has been opened since March, and which has been subjected to the constant transit of heavy trains and traffic. Some curious acoustic effects have been observed. Pistol shots, or any sonorous noises, are echoed within the tube half-a-dozen times. The cells of the top and bottom are used by the engineers as speaking tubes, and they can carry on conversations through them in whispers; by elevating the voice, persons may converse through the length of the bridge—nearly a quarter of a mile. On Monday, 21st October, 1850, the permanent public opening of the new line of tubes for the down line, from London to Dublin, took place; the great structure being in all important respects completed. On the 19th October, the Government inspector went over it, and instituted, in conjunction with the engineers, a long series of experiments. The first experiment consisted in passing two locomotive engines through the tube, and resting them at intervals in the centre of the sections. A train of 28 waggons and 2 locomotives, with 280 tons of coal, was drawn into all four of the tubes, the deflections being carefully noted. These deflections were ascertained to be exactly three-quarters of an inch under this load. After repetitions of these experimental ordeals, which occupied several hours, the train of 280 tons, with its two locomotives, was removed about a mile distant from the tube, and then suddenly shot through it with the greatest attainable velocity; and the result was, that the deflection at this immense velocity of load was sensibly less, in the way of undulation, than when the load was allowed to remain at rest in the tube. The contrivance by which the effects are indicated, with great precision, consists of a large pipe containing water, laid along the lower cells of the tube, one end rising up within the tube at the centre, and the other end fixed against the stonework of the abutments of the bridge. Both extremities of this pipe are furnished with glass tubes and graduated scales, by which the relative levels of the water can be easily ascertained. As the slightest leakage or evaporation, over the ordinary thermometric expansion of the water, would derange the level, while only half the actual deflection of the tube was registered at each end of the pipe, these disadvantages are obviated by the addition of a large reservoir of water in the interior of the tube, which is covered with oil, and placed beside the graduated scale. This larger area exhibited the whole of the deflections at the abutment extremity, and the apparatus presents a perfect representation of all the deflections and phases of the great structure. Messrs. E. and L. Clark, the resident engineers, who have watched minutely from day to day all the developed peculiarities of the novel undertaking, state that the heaviest gales through the straits do not produce so much motion over the extent of either tube as the pressure against the side of the tubes of ten men; and that the pressure of ten men, keeping time with the vibrations, produces an oscillation of $1\frac{1}{4}$ inch; the tube itself making 67 double vibrations per minute. The strongest gusts of wind that have swept up the channel during the late stormy weather do not cause a vibration of more than $\frac{1}{4}$ inch. The broadside of a storm causes an oscillation of less than an inch; but when the two tubes are braced together by frames, which is now being done, these motions, it is expected, will cease. The action of the sun at midday does not move them more than $\frac{1}{4}$ or $\frac{3}{8}$ths of an inch. The daily expansion and contraction of the tubes varies from half-an-inch to three inches, attaining either the maximum or minimum at about 3 o'clock A.M. and P.M. If a compass be held over any part of the bottom of the cells, the south pole is affected, and if held over the top of the cells, the north pole is affected; and this effect is observable in all parts of the tube, whether at the centre or the end, although their position is only about 10° west of the magnetic meridian. Preparations are making for covering the tubes with a light arched roof, of peculiar construction.

(1) For this figure, as well as Figs. 343, 353, we are indebted to the *Illustrated London News*.

The following is an official return of the cost of the entire structure:—

Pedestals and abutments on Caernarvon side	£17,459
Caernarvon tower	28,626
Britannia tower	38,671
Anglesea tower	31,430
Pedestals and abutments on Anglesea side	40,470
Lions	2,048
Total for Masonry	158,704
Wrought-iron used in tubes	118,946
Cast-iron in tubes and towers	30,619
Construction of tubes	226,234
Pontoons, ropes, capstans, painting materials, &c.	28,096
Raising machinery	9,782
Carpentry and labour in floating, raising, and completing bridge	25,498
Experiments	3,986
Total	£601,865

The entire bridge, including both lines, contains nearly a million and a half cubic feet, or 105,000 tons, of masonry, 44,200 cubic feet, or 9,480 tons, of wrought-iron, and 1,988 tons of cast-iron. The two tubes, in their complete state, contain 9,360 tons of wrought-iron, 1,015 tons of cast-iron, and 165 tons of permanent way. They are composed of about 186,000 separate pieces of iron, pierced by seven millions of holes, and united by upwards of two millions of rivets. They contain 435,700 feet or 83 miles, of angle-iron; and their total weight is 10,540 tons.

BRIMSTONE, (from the Saxon *Brenne-stone*, a stone that burns.) [See SULPHUR.]

BRINE-WELLS. [See SALT.]

BROMINE, (from βρῶμος, a noisome smell.) An elementary substance, discovered in 1826 by M. Balard, of Montpellier, in the bittern, or uncrystallizeable residue of sea-water. It is contained in minute quantities in sea-water, and is a frequent constituent of saline springs, chiefly as bromide of magnesium. There is a celebrated spring of this kind near Kreutznach, in Prussia, which is the chief source of bromine as an article of commerce.

At common temperatures, bromine is a red thin liquid, of an exceedingly intense colour, very volatile, and of a very suffocating and offensive odour. Phosphorus ignites spontaneously in its vapour: tin and antimony also burn in it. Bromine freezes a little below zero, and boils at 116°. The density of the liquid is 2.96, and that of the vapour 5.393. Bromine is fatal to animal life. It is slightly soluble in water, more freely in alcohol, and most abundantly in ether. The aqueous solution destroys vegetable colours. Bromine forms hydrobromic acid with hydrogen, and bromic acid with oxygen.

BRONZE is an alloy of copper and tin, used by the ancients for casting statues and other ornaments. In the following table, the composition of several ancient bronzes is given, showing the number of ounces of tin added to each pound of copper.

¾ oz. Ancient bronze nails, flexible; or, 20 copper, 1 tin.

1¾ oz. Soft bronze; or 9 to 1.

2 oz. Medium bronze; or 8 to 1.

2¼ oz. Hard bronze; or 7 to 1.

6 to 8 oz. Ancient mirrors.

According to various modern analyses, ancient weapons and tools contained from 8 to 15 per cent. of tin; medals, from 8 to 12 per cent. tin, with 2 parts zinc added to each 100, for improving the bronze colour.

The modern alloys of copper and tin have led to the production of a variety of metals, bearing different names, and applied to different uses. The principal of those which have as yet been discovered are—

1 oz. Soft gun-metal, that bears drifting, or stretching from a perforation.

1⅓ oz. A little harder, fit for mathematical instruments; or, 12 copper, and 1 very pure grain tin.

1½ oz. Still harder, and fit for wheels to be cut with teeth.

1½ to 2 oz. Brass ordnance; or, 8 to 12 per cent. tin. The general proportion is one ninth-part of tin.

2 oz. Hard bearings for machinery.

2½ oz. Very hard ditto.

3 oz. Soft musical bells.

3½ oz. Chinese gongs, and cymbals; or, 20 per cent. tin. This alloy, when newly cast, is very brittle; but, by being plunged at a cherry-red heat into cold water, and confined between two discs of iron, to keep it in shape, it becomes tough and malleable.

4 oz. House-bells.

4½ oz. Large bells.

5 oz. Largest bells.

7¼ to 8¼ oz. Speculum metal. In some cases, 1 oz. of brass is added to each pound, for the purpose of introducing a small portion of zinc. In other cases small proportions of silver or arsenic are added. The Earl of Rosse says:—"Tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other with which I am acquainted; the best proportions being 4 atoms of copper to 1 of tin; in fact, 126.4 parts of copper to 58.9 of tin." The object appears to be the exact saturation of the copper with the tin; but in this, as in every other alloy, the proportions differ with the degrees of purity of the metals. "When the alloy is perfect, it should be white, glassy, and flaky. When the copper is in excess, it imparts a red tint, easily detected; when the tin is in excess, the fracture is granulated, and also less white." The melted tin should be poured into the fluid copper at the lowest temperature that a mixture can be produced by stirring. The mixture is then poured into an ingot, and the combination completed by gradually remelting, putting the metal into the furnace almost as soon as it is lighted. Trial is made of a small piece taken from the pot before pouring.

32 oz. of tin to 1 lb. of copper make an alloy called by pewterers *temper*, which is added in small quantities to tin for some kinds of pewter, called *tin and temper*, in which the copper is often less than 1 per cent. [See PEWTER.]

The addition of tin continually increases the fusibility of the alloy, although, when added cold, it is apt to make the copper pasty, or even to set it in a solid lump in the crucible. In the proportion of 2½

oz. to the pound, the tin does not greatly impair the red colour of the copper. It becomes greyish white at 6, and quite white at 8. Beyond this the alloy has a blueish cast. The alloy is scarcely malleable at 2 oz., and it soon becomes hard, brittle, and sonorous. Alloys of $1\frac{1}{2}$ cut easily; at $2\frac{1}{2}$ they are at the hardest, without being crystalline; beyond this they crumble under the file, until the tin is greatly in excess, as in the pewters, when the alloys become flexible, soft, malleable, and ductile, the less the proportion of copper.

In some bronzes small proportions of zinc and lead are added. For gilt ornaments of bronze it has been recommended to employ 82 parts copper, 18 zinc, from 3 to 1 of tin, and from 3 to $1\frac{1}{2}$ of lead. Such an alloy has a close grain; but the lead diminishes the tenacity, and increases the density. Another alloy, which is said to require only a small quantity of gold in the gilding, is composed of copper 82.257, zinc 17.481, tin 0.238, lead 0.024.

The antique bronze colour is given to bronze figures by the following process:—Two drachms of sal-ammoniac and half a drachm of binoxalate of potash are to be dissolved in 14 ounce-measures of colourless vinegar. This solution is to be applied with a hair-pencil in a very thin layer, the object having been previously warmed gently; and the operation is to be repeated until the desired colour is produced.

For the casting of bronze statues, &c., see CASTING.

A cheap method of forming articles in bronze, by the electrotype process, has recently been introduced. In 1841, M. de Ruolz communicated to the Academy of Sciences at Paris a process by which he bronzed metals, by depositing on them, by means of the voltaic battery, coatings of brass or bronze, of variable thickness. This process required the use of the double alkaline cyanides of copper and zinc, or copper and tin, the high price of which precluded their use in practice. Instead of these cyanides, MM. Brunel, Bisson and Gaugain employ an aqueous solution of 500 parts carbonate of potash, 20 parts chloride of copper, 40 parts sulphate of zinc, 250 parts nitrate of ammonia. In order to obtain bronze, a salt of tin is substituted for the zinc. By means of these solutions, wrought or cast-iron, steel, lead, zinc, tin, and the alloys of these metals, either with each other or with bismuth and antimony, may readily be coated with brass or bronze, after being properly cleaned or scoured, according to the nature of the metal. The operation is performed at the ordinary temperature. The article to be coated is put in communication with the negative pole of a Bunsen battery; the positive decomposing pole being a plate of brass or bronze. When large surfaces are to be coated, the number of pairs of plates, not their size, must be increased. When the articles have been coated, and coloured in the usual way, they are equal in beauty to the finest bronzes. Rough cast-iron may by these means be made to assume a very beautiful appearance; and articles thus coated will be preserved from rust in-doors; but if intended for the open air, they must be protected by a suitable varnish. In 1847, a patent founded on this method was granted to C. de la Salzede.

BRONZING is the art of communicating to articles in metal, wood, ivory, clay, or plaster, the effect of bronze statues. An important ingredient in bronzing is *gold-powder*, which is prepared in the following manner. Leaf-gold is ground with virgin honey on a stone, until the leaves are broken up and minutely divided. The mixture is then removed from the stone by a spatula, and stirred up in a basin of water, whereby the honey is melted, and the gold set free. The basin is then left undisturbed until the gold subsides. The water is then poured off, and fresh quantities added, until the honey is entirely washed away; after which the gold is collected on filtering-paper and dried for use. An inferior powder, called *German gold*, is prepared in a similar manner. There is also a third, which is in very common use, called *aurum mosaicum*, or *musivum*, and is prepared in the following manner:—A pound of tin, 7 oz. of flowers of sulphur, half a pound of pure mercury, and half a pound of sal-ammoniac are the ingredients. The tin is melted in a crucible, and poured into the mercury: when this amalgam is cold, it is reduced to powder, and ground with the sal-ammoniac and sulphur until the ingredients be well incorporated. They are then calcined in a matrass, and the sublimation of the other ingredients will leave the tin in the state of aurum mosaicum at the bottom of the glass, in the form of a bright flaky gold powder. Any black or discoloured particles must be removed. These powders are commonly used in bronzing; but when a shade of red is required, to resemble copper, it can be given by grinding a very small portion of red-lead with the ingredients. *Copper-powder* is prepared by dissolving filings or strips of copper with nitrous acid in a glass flask. When the acid is saturated, the slips are removed, or the solution is poured off from the filings. Small iron bars are then put in, which will precipitate the copper from the saturated acid in the form of a powder resembling copper. The liquid is then to be poured off, and the powder washed repeatedly with water. *Gold-size*, also used in bronzing, is prepared from a pound of linseed oil, with 4 oz. of gum animi. The latter is reduced to powder, and gradually added to the oil while being heated in a flask, stirring it after every addition, until the whole is dissolved. The mixture is boiled until a small quantity, when taken out, is somewhat thicker than tar, and the whole is strained through a coarse cloth. When used, it must be ground with as much vermilion as will render it opaque, and at the same time be diluted with oil of turpentine, so as to make it work freely with the pencil.

In bronzing plaster figures, a cement may be used or not; but if used, the bronzing will be more durable. If a cement be used, the powders are mixed with strong gum-water or isinglass, and laid on with a pencil or brush. Some artists begin from the bottom, and work upwards. The subject to be bronzed may also be covered with gold-size, diluted with turpentine, and being allowed to dry very nearly, a piece of

soft leather, wrapped round the finger, is dipped into the powder, and rubbed over the work, or the powder may be spread with a soft camel's-hair pencil. When the whole is covered, it is left to dry, and the loose powder is then cleaned off with a hair pencil. Much of the effect depends on applying the powder at the proper point of dryness. The precise tint, and the proper distribution of light and shade, must be left to the taste of the artist.

For bronzing on wood, prussian blue, patent yellow, raw umber, lamp-black, and pipe-clay, are separately ground with water on a stone, and as much of them as will make a good colour is put into a small vessel containing sufficient size to produce not quite that strength called *clean size* in gilding. The wood having been cleaned and smoothed, is coated with a mixture of clean size and lamp-black: it is then coated twice with the above ingredients, drying between each application. The bronze powder is then applied with a pencil, and the whole is burnished or cleaned. The parts injured by this process having been repaired, the work is coated with a thin lather of Castile soap, which will take off the glare of the burnishing: it is then carefully rubbed with a woollen cloth. The gangrenous appearance of the cavities is produced by wetting them slightly with a hair-pencil dipped in the lather, and then sprinkling them with a little dust of verditer gum. When dry, the superfluous powder may be rubbed off.

Copper-coins and medals may be bronzed by the following process:—Dissolve in vinegar 2 parts verdigris and 1 part sal-ammoniac. Boil, skim, and dilute the solution with water until it ceases to let fall a white precipitate. The solution is then made to boil briskly, and is poured upon the objects to be bronzed, previously made perfectly clean and free from grease, and set in a copper pan, which is to be put on the fire and the boiling renewed. The pieces must be so arranged that the solution may be in contact with every point of their surface. The copper thus acquires an agreeable reddish-brown hue without losing its lustre, but it is necessary to inspect the articles every five minutes and to remove them from the solution the moment the desired shade is attained. The pieces must then be washed repeatedly with water and carefully dried. If the solution has been too strong, the bronzing will come off with friction, or turn green by exposure to the air.

An antique bronze appearance may be given by dissolving 1 part sal-ammoniac, 3 parts cream of tartar, and 6 parts common salt, in 12 parts of hot water. This solution is to be mixed with 8 parts of a solution of nitrate of copper, specific gravity 1.160. When this compound is applied repeatedly, in a moderately damp place, to articles of bronze, it gives them a durable green coat which gradually increases in beauty. By increasing the proportion of common salt, a yellowish tinge is produced; by diminishing it, a bluish cast is obtained. A large addition of sal-ammoniac hastens the process.

The browning or bronzing of gun-barrels and other articles of iron consists in giving them a shining brown colour, which improves the appearance, protects them from rust, and in the case of gun-barrels serves to conceal them from the game and the enemy.

By one operation a thin uniform film of oxide of iron is raised on the surface, and the gloss is given by rubbing wax over it or coating it with shell-lac varnish. The film of oxide is produced by exposing the iron in a close place to the vapour of muriatic acid, or by moistening the surface with dilute muriatic or nitric acid. Butter or chloride of antimony, called *bronzing salt*, is commonly used. It is mixed with olive oil, and rubbed upon the iron slightly heated: a greater or less exposure to the air produces the desired degree of browning. The operation is quickened by rubbing in a little nitric acid after the antimony has been applied. The barrel is then carefully cleaned, washed with water, dried and polished either by a steel burnisher, or rubbed with white wax, or varnished with a solution of 2 oz. of shell-lac and 3 drachms of dragon's blood in 2 quarts of spirit of wine.

The finest kind of browning is the Damascus, in which dark and bright lines run through the brown ground. To produce this, the barrel is rubbed over with very dilute aquafortis and vinegar, mixed with a solution of sulphate of copper. It is then washed and dried and rubbed with a hard brush to remove any scales of copper.

The reader interested in the subject of Bronzing will find a vast number of recipes scattered through different works on Metallurgy and the Fine Arts, &c. He must be cautious in compounding the ingredients, for some of the mixtures throw off fumes which are dangerous if inhaled, and others will corrode ordinary vessels. Indeed, it is generally dangerous for an amateur to concoct the recipes which he finds in books unless he be a tolerable chemist.

BRUSH. An assemblage of hairs, hogs' bristles, strips of whalebone, vegetable filaments, &c., fastened together in a handle, or in holes drilled for the purpose in a stock of wood or bone. Brushes may be round, flat, or square; and they are named according to the uses to which they are applied. The smallest kind of brush, such as is used in water-colour drawing, is called a *hair pencil*, and the hair employed may be that of the camel, the badger, the squirrel, the goat, and some other animals. Hair pencils are made by collecting a small tuft or bundle of hairs, with the points all in one direction, and binding the root ends firmly together with strong thread. The points being temporarily secured, the tuft is put into the wide end of a piece of quill tube, previously softened and made pliable by wetting, and is passed down the tube until the points project at the small end, the superior thickness of the roots and the binding-thread preventing the tuft from passing completely through; and the tube, in drying, contracts, and holds the tuft securely. The broad end of the quill forms a socket for the reception of a stick of cedar-wood. Some care is required in making hair pencils, for if the tuft be not properly put together, or if pinched too tightly,

either by the thread or by the contraction of the quill, the hairs will spread out instead of forming a fine point, which they ought to do when wetted. Hair pencils are made of various sizes, from that of a small crow or pigeon quill to the largest goose, turkey, or swan quill; and when larger than these are required, tin-plate tubes are used, with the handle or stick firmly secured therein. The ancients had pencils made of small pieces of sponge, whence the story of the painter who, not being able to express the foam of a horse, succeeded by throwing "the sponge" at the picture.

Bristles, however, form by far the chief article in the manufacture of brushes; and the consumption is so vast as to give rise to a very important commerce in this article. They form the strong glossy hairs growing on the back of the hog and wild boar. Russia is the great mart for bristles, those of the Ukraine being most esteemed. Of the total quantity imported in 1841, amounting to 1,735,502 lbs., Russia furnished 1,419,514 lbs., Prussia (Königsberg) 132,136 lbs., and Germany 130,899 lbs. At an average of the three years ending with 1842, the entries for home consumption amounted to 1,772,196 lbs. a-year. The duty, which varied from 2*s.* 6*d.* on rough, to 3*s.* per cwt. on sorted bristles, produced, in 1842, 24,100*l.* 17*s.* 11*d.* nett. Bristles have been free of duty ever since the 19th March, 1845, in which year the number of pounds imported amounted to 2,412,267.

A considerable quantity of bristles is also imported from France. These are of various colours; but that which is called the *lily*, on account of its silvery white appearance, is most esteemed. It is used chiefly for shaving-brushes, tooth-brushes, and the softer descriptions of hair-brushes. The thickest bristles are the most valuable, and the price diminishes with the size of the bristles.

Bristles, as taken from the animal, are of various colours intermixed; but, before being used, and sometimes before being imported, they are sorted by hand into *black, grey, yellow, white,* and *lilies,* the last variety being the lightest. A bundle of any of the other varieties generally contains many shades of colour, which are carefully intermixed when it is intended to use them together. The bristles being sorted into different colours, they are next sorted into different sizes by a process called *dressing;* for which purpose a number of combs, called *engines,* Figs. 365, 366, formed by thrusting the heads of needles, of various

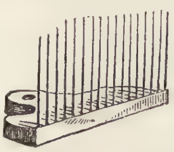


Fig. 365.

Fig. 366.

sizes, and at various distances apart, into blocks of wood, are set up on a bench before the workmen, six or eight of these combs being commonly used. He then takes a bundle of bristles, weighing from $\frac{3}{4}$ lb. to 4 lbs., and opening the bundle, strikes the bristles upon the first or widest comb, and draws them through. By repeating this operation several times the largest and stoutest bristles are retained between the teeth of the first comb. He then passes on to the second comb, which, in like manner, retains those bristles which are a little smaller than the first; and in this way he proceeds until the whole bundle is separated into as many degrees of fineness as there are combs. The dressed hairs are, for the finest work, again picked, and all the different shades of colour collected into separate heaps, care being taken in all these operations to keep the root ends together.

The simplest form of brush is that denominated a *tool.* It is of various sizes and forms, the cylindrical and the flat being most common. In the larger bristle-tools, used in house-painting, the bristles are taken of the whole length, and are tied firmly to the end of a wooden stick or handle, cut into a forked shape. The bundle of bristles being inserted between the two projecting prongs, is secured by twine, and the twine is protected by a coating of glue, mixed with red lead, to render it less soluble. In another kind of brush, the handle, instead of containing the tuft, as in the above example, is inserted into the tuft, as in the large painting and dusting brushes, used by house-painters. The bristles are first wrapped round the smaller end of the conical wooden handle, and, being properly secured, are placed in a thin hollow iron block, perforated in the centre for the handle to pass through, and forming around this hole a sort of cup for the bristles: the handle is then driven in with considerable force, so that the thick end is held firmly in the centre, as a sort of core, and, by pressing the bristles tightly against the side of the iron, holds them securely.

Stock-brushes, used as whitewash and distemper brushes, consist of two or more cylindrical brushes, placed side by side, and fastened separately upon the edge of a flat stock or handle, each brush being divided into two semi-cylindrical portions by the thin edge of the stock between them.

The commonest form of brush or hair-broom[1] is formed by the insertion of a number of tufts or knots of bristles into holes drilled in a stock of wood. There are two methods of doing this, the first and simplest of which applies chiefly to the making of brooms. The heads or stocks are bored to a sufficient depth by means of the boring bit and brace, and where the bristles are intended to spread out obliquely, the holes are bored to the proper angle. In many cases, however, the stock is formed with a curved face, so as to give the proper spread or *splay* to the brush. The tufts are inserted by what is called *pan* or *set-work.* Three or four men, seated round a small charcoal stove, containing a pan, about three inches deep, of melted pitch, Fig. 367, proceed in the following manner. Each man takes up a number of bristles sufficient for one knot, and

(1) *Broom* is so called from its having been originally made of the small branches of the plant of that name. *Brush* is supposed to be so called because it is made of *brustles* or *bristles.* Skinner suggests that *bristle* is from the verb to *brust* or *burst,* because the bristle *bursts* through the skin.

strikes the ends on a board or smooth stone until they are even and regular; then, holding them tightly near the ends which are to be inserted, he dips these ends into the pitch, and, taking them out, scrapes them against one of the edges of metal seen in the pan, by which means he removes the superfluous pitch, and drives a portion of it into the interior of the mass. He next quickly takes a *thrum* of string, a few inches long, and winds it round the pitched ends of the bristles, Fig. 368, dips it again into the pitch, and immediately inserts it into the hole in the stock, Fig. 369, with a twisting sort of motion. The pitch almost immediately sets, and holds the knot so securely that it is impossible to pull it out by hand. Long brooms, bannister-brushes, hearth-brushes, dusting-brushes, (technically called *set dusters*, to distinguish them from painters' dusters,) are made by this process, the bristles being commonly of the whole length. In Thomason's iron constat hearth-brush, the bristles are concealed in a case, and, by the action of pulling in a tube, the bristles are protruded; the object being to conceal them from the eye when the brush is not in use. The handle and tube are made ornamental, and the bristles, being out of sight, do not offend the eye, nor soil the wall near which they are hanging.

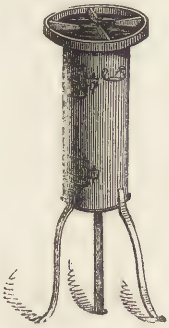


Fig. 367.

Fig. 368.

Fig. 369.

Brushes used for laying on colour, for dusting or sweeping, require much less force than those used in the operations of *brushing*, as the term is commonly understood. The increased hardness or stiffness of a brush is obtained by folding up each tuft of bristles, so that each bristle may present its two ends upwards; and these being cut square and even, a hard surface is presented, especially when this doubling is performed near the root ends, which are much stronger and more durable than the *flag* or taper ends of the bristles.

The stocks, or brush-boards, are made of almost every description of wood; birch, beech, oak, and chestnut being most common; while for the best brushes satin and rose-wood are used. These boards are supplied by the timber merchant of the requisite thickness either for drilling or for veneering. The boards are economically cut, as in Fig. 370, so as to get two brushes out of each board. The drilling is performed in a small lathe, in which the drill projects in a direct line from the operator, as in Fig. 371; and, in order to bore the holes correctly, a *scale*, or pattern-board, ready drilled, (thousands of these scales being kept on hand,) is attached by clamps to the board which is to be drilled. All, therefore, that the man has to do, is to pass the drill through the holes of the pattern into the board attached to it. If the board have bevelled edges, in which the bristles are inserted in an oblique position, a leaden pattern or scale is used: this can be bent to any degree of *spread* that may be required. In some cases, the holes are drilled not entirely through the board, but only as far as the tuft is intended to go; after which, a small tool, called a *bore-through-bit*, is fixed in the lathe, and with this smaller holes are drilled through the stock, in continuation of the larger holes. After the drilling, the boards are cleaned off with a plane, to make the holes smooth, and in some kinds of brush the face is French-polished.

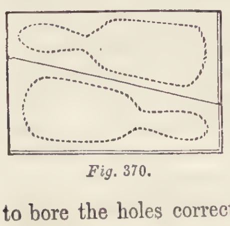


Fig. 370.

Fig. 371. DRILLING THE BRUSH-BOARDS.

Then comes the operation of *drawing*, which employs by far the larger number of hands in the trade. This is generally done by females, who are seated round a table, each with a lapful of bristles (Fig. 372). Each woman places a drilled stock in a holdfast secured to the table, and passing the loop or bite of a thin flexible brass wire through a hole at the end of the first row, takes up a number of bristles sufficient to half fill the hole, if inserted in lengths, and passes through the wire loop a portion of the root ends of this tuft, previously made to lie square and even by adjusting them between the finger and thumb, and trimming the tuft by pulling out stray bristles. She then pulls the wire firmly, the effect of which is to double up the tuft, and to pull the part thus doubled into the hole as far as it will go, until it is stopped by the resistance of the wood, or by the shoulder formed by the termination of the larger bore and the commencement of the smaller one. Then, bending the wire again into a loop, it is passed through the next hole, and another tuft of bristles being inserted, the loop is drawn as before. In this way the drawing proceeds, until a complete row is formed.

when a man takes the stock, and cuts off the ends of the row with shears, to which a gauge is attached, for regulating the precise length of the tufts which are to be left. If the brush is to be what is called a

Fig. 372. BRUSH-DRAWING.[1]

penetrating brush, the bristles are cut of uneven lengths: otherwise they are reduced to the same level. If the bristles have been properly drawn, little or nothing is taken off the root ends; but the pieces cut off from the flag ends are often sufficient to form fresh series of tufts for inferior brushes, or they are worked up in a row of tufts just within the edge of the brush, where, having the heart or centre of the brush on one side, and the outermost row of tufts on the other side, to protect them, they are less exposed to wear. If the bristles are not very long, the drawing is continued without interruption until the stock is full: the projecting ends are then trimmed by hand. The following figures represent brushes in

Fig. 373.

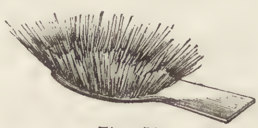


Fig. 374

Fig. 375.

Fig. 376.

their unfinished states. Fig. 373 is the back of a brush, drilled and drawn. Fig. 374 is the face of an oval brush, after drawing. Fig. 375 the face of a brush with the heart filled in with black bristles, surrounded by a border of white bristles. Fig. 376 is the same after it has been cut and finished. A skilful drawer will draw 500 tufts an hour; but many drawers do not accomplish more than 100. A brush may be drilled with a number of holes varying from 100 to 800.

The drawing-wires at the back of the stock, Fig. 373, are covered over with veneers, not only for the sake of appearance, but also to prevent the wires from hurting the hand in using the brush. In scrubbing and other brushes exposed to wet, the wire soon becomes corroded, notwithstanding the veneer; but, if the drawing be well done, the tufts are held so tightly that they will not give way, unless the brush be allowed to get very dry; in which case the shrinking loosens the tufts, and they fall out with the wear. The *stopping-brush* used by the beaver-hat maker resembles a common scrubbing-brush; but the bristles are drawn with cord instead of wire, which would be corroded by the hot acid liquor of the hat-battery.

The veneer is applied to the back of the brush by holding both before the fire, then covering them with a layer of glue, and applying the glued surfaces together. They are inserted between the jaws of a number of hold-fasts, (one of which is shown in Fig. 377,) and these being screwed up tightly, the veneer in drying becomes firmly attached to the back of the brush. In some cases, a number of thin veneers (from two to six) of different coloured woods, are glued to the back, and in shaping the brush, these are cut obliquely, so that their chamfered edges present a number of lines of different colours.

During all these operations, the form of the brush is similar to one of the three Figs. 374, 375, or 376.

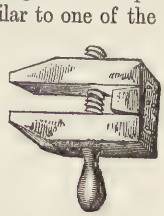


Fig. 377.

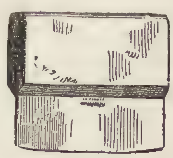


Fig. 378.

Fig. 379.

It is now to be reduced to shape, which is done by means of the spoke-shave, Fig. 379, and the scraper, Fig. 378. When reduced to the proper form, it is rubbed over with sand-paper and varnished.

Drawn brushes include hair-brushes, scrubbing-brushes, shoe-brushes, clothes-brushes, &c. &c. Also tooth and nail brushes; but, from their small size, and greater neatness of work, these latter form a distinct branch of the trade. In these, the bristles are drawn with a very thin wire (sometimes of silver), sunk in narrow grooves in the back, which are afterwards filled up with a hard red cement. The best sort of brushes are *trepanned;* that is, the drawing-holes, instead of being pierced completely through the back,

(1) In this figure, the artist has made the drawer left-handed. The stick round which the wire is wound ought to be in her right hand. Mr. Withers, who revised this notice, says:—"Although I never saw a left-handed drawer, it does not follow that it cannot be done in that way."

are formed in the following manner. A number of tunnels are drilled through the thickness of the bone, either at the side or at the end; then a number of holes, corresponding with the number of tufts of bristles, are drilled in the face of the bone down into these tunnels; the tufts are then drawn with strong thread or silk, instead of wire, and lastly, the small lateral holes are plugged up with small pieces of bone or ivory, and the whole is smoothed and polished.

Brushes for cleaning bottles are formed by inserting a number of tufts of bristles between two or three parallel wires, at right angles to their length. Then, by twisting the wires together, the tufts are made to radiate around the central axis. Soft brushes, such as hat-brushes, are formed of horse-hair or goats'-hair. Some kinds of hard brushes are formed of strips of whalebone. The whalebone is boiled or steeped in water until it has become soft and flexible, so as to admit of being cut with a sharp instrument into thin shavings, which are split by a number of lances fixed in a handle. They are first cut into lengths of 9, 12, or 18 inches: the strips are then dried, and are used in the same manner as natural bristles. Coarse brooms, for stable and out-door use, are commonly made of *bass*, a hard, tough, dark-coloured vegetable fibre: birch and heath are also used. *Wisk* is a light-coloured vegetable fibre, used chiefly for carpet-brooms: and the finest variety is used in making brushes for cleaning velvet.

In 1830, Mr. Mason took out a patent for fixing the knots or tufts of brushes in dovetailed grooves formed in the stock, in order to supersede the slow process of drawing. Mr. Hancock has also a patent for the manufacture of brushes with flexible backs, in which the tufts are attached to yielding backs of leather.[1]

The Rev. Gilbert White, in his "Natural History of Selborne," mentions "a pretty implement of housewifery," which he had not seen anywhere else: "That is, little neat besoms, which our foresters make from the stalks of the *polytricum commune*, or great golden maiden-hair, which they call silk-wood, and find plenty in the bogs. When this moss is well combed and dressed, and divested of its outer skin, it becomes of a beautiful bright chestnut colour; and being soft and pliant, is very proper for the dusting of beds, curtains, carpets, hangings, &c. If these besoms were known to the brushmakers in town, it is probable they might come much in use for the purpose above mentioned."

BUDE-LIGHT. [See GAS.]

BUHL-WORK, or *bool-work*, a term probably corrupted from *Boule*, and applied to any two materials of constrasted colours, inlaid with the saw. In France, the general term, *marqueterie*, is applied to such works, and to all kinds of inlaid work; and it is distinguished into *marqueterie en bois* and *marqueterie en metal*. It consists in representing flowers, animals, landscapes, and other objects, in their proper tints, by inlaying, without the aid of the artist's pencil: it also includes those geometrical patterns composed of angular pieces laid down in succession, after the manner of ordinary veneering, and to which the specimens of *parquetage* or inlaid floors belong. But the terms, *Buhl-work* and *Reisner-work*, appear to have originated in the names of the original inventors, two celebrated *ébénistes*, named Boule and Reisner—the one an Italian, and the other a German. The former settled in France in the reign of Louis XIV., and the latter in the time of Louis XIV. to XV. Their cabinet works were as much celebrated for their graceful forms as for their embellishment with inlaying. Boule chiefly employed dark-coloured tortoise-shell, inlaid with brass in flowing patterns, sometimes ornamented by the use of the graver. Reisner used principally as the ground tulip-wood, (*bois de rose*,) inlaid with flowers in dark woods. He also occasionally combined therewith bands and margins, in which the woods were contrasted as to the direction of the grain, as well as colour.

In buhl-work, as now constructed, the patterns generally consist of continuous lines, as in the honeysuckle ornament. To form this, two pieces of veneer, of equal size, such as ebony and holly, are scraped evenly on both sides, and glued together, with a piece of paper between. A piece of paper is also glued outside one of the veneers, and on this the design is sketched: a small hole is then made for the introduction of the saw, in a place where the hole will not be noticed in the pattern.

The saws used in piercing and inlaying differ but in size. The thin black line, Fig. 381, is the piercing-

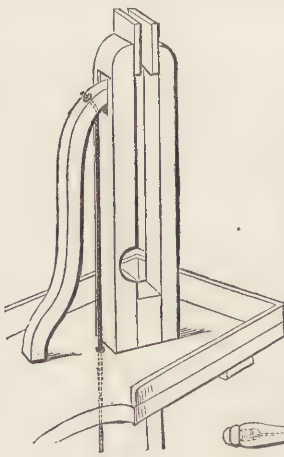


Fig. 380.

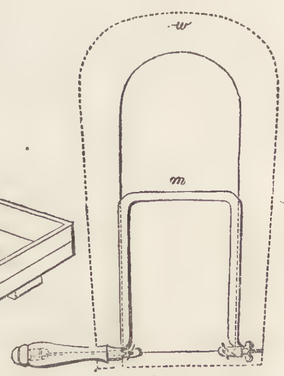


Fig. 381.

saw, attached to its handle and frame, *m*, and the dotted line, *w*, is the wooden frame of an ordinary buhl-saw: the former measures 8 inches from the blade to the frame; the latter 12 or 20 inches, to avoid the angles of large works. The wooden frames are made of three pieces of wood, halved and glued together, to form the three sides of a rectangle; after which, two pieces are glued upon each side, at an angle of 45°, across the corners: the whole, when

(1) For the illustrations and much of the information contained in this article, the Editor is indebted to Messrs. Withers, Brush-manufacturers, Tottenham-court Road, London.

thoroughly dry, is cut round to the form represented in Fig. 381.

The buhl-cutter sits astride a horse, or long narrow stool, Fig. 380, at one extremity of which are two vertical jaws, lined with brass at the top: one jaw is fixed; the other is notched below, and springs open when left to itself, but is closed by a strut, which is loosely attached to the stool by a tenon and mortice, and rests in a groove in the movable jaw. When the strut is pulled downwards by a string leading to the treadle, it closes the flexible jaw of the vice. The jaws are inclined some 20°, so as to be at right angles to the path of the workman's right hand.

Matters being thus arranged, the buhl-cutter inserts the saw into the hole in the veneers, and then fixes the saw in its frame. The work, held in the left hand, is placed in the vice, which is under the control of the foot, and the saw is grasped in the right hand, with the forefinger extended, to support and guide the frame. "The several lines of the work are now followed by short quick strokes of the saw, the blade of which is always horizontal; but the frame and work are rapidly twisted about at all angles, to place the saw in the direction of the several lines. Considerable art is required in designing and sawing these ornaments, so that the saw may continue to ramble uninterruptedly through the pattern, while the position of the work is as constantly shifted about in the vice, with that which appears to be a strange and perplexing restlessness. When the sawing is completed, the several parts are laid flat on a table, and any removed pieces are replaced. The entire work is then pressed down with the hand; the holly is stripped off in one layer with a painter's palette knife, which splits the paper, and the layer of holly is laid on the table with the paper downwards, or without being inverted. The honeysuckle is now pushed out of the ebony with the end of the scriber, and any minute pieces are picked out with the moistened finger: these are all laid aside. The cavity thus produced in the ebony is now entirely filled up with the honeysuckle of holly, and a piece of paper, smeared with thick glue, is rubbed on the two, to retain them in contact. They are immediately turned over, and the toothings or fine dust of the ebony are rubbed in, to fill up the interstices: a little thick glue is then applied, and rubbed in first with the finger, and then with the pane of the hammer, after which the work is laid aside to dry." [1] When dry, it is scraped at the bottom, and is then ready to be glued to the box or furniture to which it is to be applied: when the work is again dry, it is scraped and polished. The same course is pursued in combining the holly ground and the ebony honeysuckle, and these form the *counter* or *counterpart buhl*, in which the pattern is the same, but the colours are reversed.

Three thicknesses of wood, such as rosewood, mahogany, and satin-wood, may be glued together and cut as before. The three thicknesses, when split asunder and recombined, would produce three pieces of buhl-work, the grounds of which would be of rosewood, mahogany, and satin-wood, with the honeysuckle and centre of the two other colours respectively. Such are called "works in three woods," and form the general limit of the thicknesses.

Brass borders, called *Vandykes*, are worked in narrow slips. The true buhl, or the wood ground with brass scrolls, is laid down in four or more pieces around one box or panel, and the counter, or the brass ground with wood scrolls, upon another.

When the material is small and costly, as pearl-shell, several pieces must be used: these are placed correctly edge to edge, so as to cover the entire surface to be ornamented. The paper-knife, a portion of which is shown in Fig. 382, required eight pieces

Fig. 382.

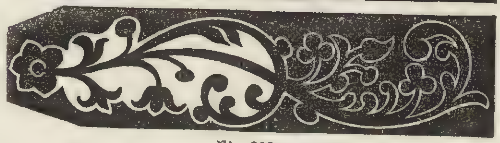


Fig. 383.

of pearl-shell. The counter, when glued on another veneer, is not inlaid of the irregular angular form of the rough pieces of pearl, but is cut round the general margin of the pattern, as in that portion of Fig. 383 which represents the counter to Fig. 382.

A more elaborate effect is produced by making the saw follow all the device of the counter, so as to leave a narrow line of pearl both within and without: this is called internal cutting, and is shown to the right of Fig. 383.

In the more minute buhl-works, the parts are not cut exactly square, but slightly bevelled, so that the pearl may be left a little larger than the interstices of the wood, to compensate for the saw kerf, and to make the fitting close, as regards the true buhl. The *stringings*, or the straight and circular lines combined with pearl buhl-work, are mostly of white metal, such as tin or pewter. Buhl-works of brass and wood are also sometimes made by stamping, instead of sawing. [See Inlaying.]

BUILDING. An art which includes the practice of civil architecture, or the mechanical operations necessary to carry the designs of the architect into effect. "The execution of works of architecture necessarily includes building; but building is frequently employed when the result is not architecture: a man may be a competent builder without being an architect; but no one can profess himself a complete architect unless he be competent to specify and direct all the operations of building. A scientific knowledge of the principles of masonry, carpentry, joinery, &c., and of the qualities, strength and resistance of materials, though of the utmost importance to an architect, is not sufficient of itself, without

(1) Holtzapffel, "Turning and Mechanical Manipulation," vol. ii.

a minute acquaintance with a great variety of less ambitious details. Such are those which relate to the arrangement of a plan for the greatest possible degree of convenience on the smallest space and at the least expense; its transference to the ground; the preparation and formation of foundations; the arrangement and construction of drains, sewers and cesspools; the varieties of walling with stone and of bonding bricks in brick-work; the merit of the various modes of bonding and tying walls with timber and otherwise; the arrangement of gutters on roofs, to get sufficient fall and to lead the water to the least inconvenient places for placing trunks to carry it down; the arrangement and formation of flues; the protection of walls from damps, of timbers from moisture and stagnant air, and of metals generally from exciting causes; the cost of materials and labour, and the quantity of each required to produce certain effects. Together with these it is important to be practically acquainted with all the modes of operation in all the trades or arts required in building. Everything must be clearly understood, or it will be impossible properly to specify beforehand, in detail, every thing and every operation to be done and performed; and minutely to estimate beforehand also the absolute cost involved in the execution of a proposed structure. The power to do the latter necessarily involves that of measuring work and ascertaining quantities after it is done. These things may certainly be referred to the surveyor or measurer, but they are not the less incumbent on the architect, who cannot be said to be thoroughly master of building, or the practice of his profession, unless he be skilled in these operations."

The foregoing enumeration of the duties of the architect, (from an excellent article on Building by Professor Hosking, in the Encyclopædia Britannica,) includes nearly all the processes concerned in building, and will form the subjects of separate articles in this work. See FOUNDATIONS—SEWERS and DRAINAGE—BRICKLAYING—STONE-MASONRY—MORTARS and CEMENTS—PLASTERING—CARPENTRY and JOINERY—ROOF—TIMBER—SLATING and TILING—PLUMBING—GLAZING—PAINTING—WARMING and VENTILATION, &c. &c.

One of the most elaborate treatises on Building is by Rondelet. "Traité de l'art de batir," 5 vols Quarto, Paris 1830—2, with a volume of illustrative plates in Folio.

BUOY. This term is supposed by Dr. Hickes to be derived from the French *bois*, wood, seeing that it is applied to the wood or block floating above an anchor, and fastened to it by a cable. In naval language the term buoy signifies any floating body employed to point out the situation of anything under water, as a ship's anchor, a shoal, sand-bank, &c. Buoys are of several kinds; the *Can-buoy* is in the form of a cone, Fig. 384, and is used to point out dangerous sands and shoals. When there are several of these near the same spot, as is frequently the case at the entrance of rivers, they are distinguished by different colours, being painted black, white, or red, or in various stripes and patterns. Red is the best colour, for in some states of the sea both black and white buoys become indistinct. The can-buoy has its apex downwards, and is painted

Fig. 384

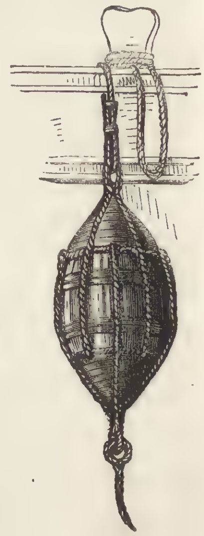


Fig. 385.

on the broad exposed surface. The *Cask* or *Cable-buoy* may be either a common cask used for the purpose, or it may be made in the form of a cask, or double frustum of a cone: it is also frequently in the form of a cylinder. The larger buoys of this

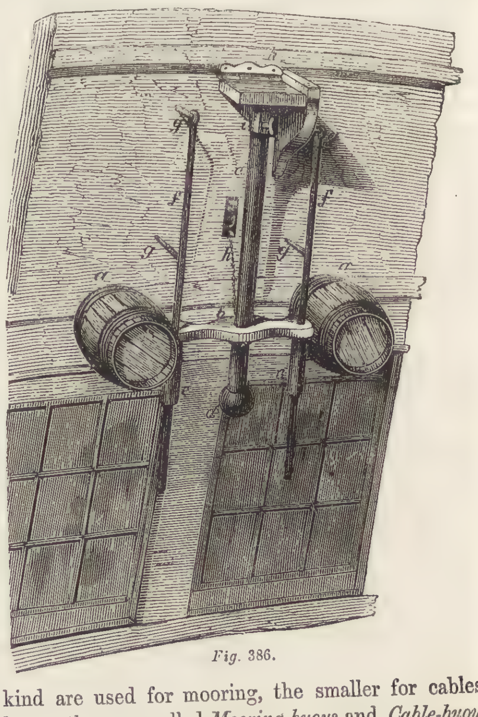


Fig. 386.

kind are used for mooring, the smaller for cables; hence they are called *Mooring-buoys* and *Cable-buoys*. *Nun-buoys* are casks which are large in the middle, and taper greatly towards the two ends, Fig. 385. *Life* or *Safety-buoys* are intended to save a person

who falls overboard, and they have been even constructed with a view to supporting several persons in case of shipwreck. The most esteemed single Life-buoy is that of Lieut. Cook of Plymouth, which is generally called a *night life-buoy,* because when an accident happens at night, it can be immediately lighted before it is let go, being provided with port-fire and lock for that purpose. Fig. 386 gives a perspective view of this life-buoy suspended over the two middle windows of a frigate stern; *aa* are two casks connected by the bar *b* passing through them, *c* a staff, *d* a ballast weight at the bottom to keep it upright; *ee* two wooden pipes firmly fixed to the bar *b*; these pipes slide on two metal rods *ff*, which are fastened to the stern at *gggg*; a chain *h* suspends the life-buoy and with the rods keep it tight to the stern; a copper cap is hinged to the stern at *k*, this covers the copper table which carries the port-fire, and defends it from the weather. This port-fire is lighted by means of a laniard *p* at Fig. 387, which pulls the trigger; a bolt is then drawn, which lets go the chain by which the life-buoy is suspended to the stern. This bolt *r* is shown at Fig. 388, in the position it is in when, being withdrawn, it has unlocked the roller *q*, which has therefore turned round and let go the chain it previously supported. The buoy with its lighted port-fire then falls into the water and furnishes a common point of resort both to the person in the water and the boat sent out to save him. The inventor obtained the gold medal of the Society of Arts, and his buoy is now in common use. A variety of other buoys and life-preservers have been brought forward from time to time. Thus, Lieut. Irvine has contrived a safety portmanteau capable of excluding moisture and of buoying up a person in the water. Capt. Hervey's life-preserver is a light wooden frame shaped like a horseshoe, but sufficiently wide to admit a man's body, and rendered buoyant by means of cork. Mr. Taylor of Leith has devised a deck seat 28 inches long by 18 broad, capable of being quickly converted into a tight boat-shaped vessel nearly 4 feet long, in which one person can float. Safety jackets and belts are numerous, and Messrs. Mackintosh have introduced a life-cloak or cape consisting of a double thickness of cloth; the space between being inflated with air forms a boat capable of floating the person. Mr. Reece has invented an India-rubber pad or cushion to be attached to the back to enable the wearer to float in water: a wire gauze mask is tied over the mouth and nostrils which admits air but repels water. Mr. Symington's jacket or belt admits of being quickly put on, and has sufficient buoyancy to keep the head of the wearer above water. It unfortunately happens with contrivances of this kind, that when there is no danger they are neglected and forgotten, so that when most wanted they are either not to be found or they are out of repair, or unmanageable. [See Boat.]

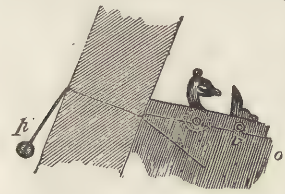


Fig. 387.

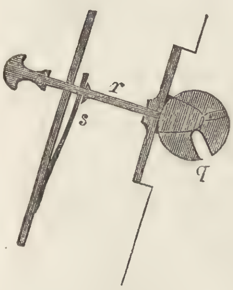


Fig. 388.

BURNER. See Gas—Lamp.

BUTTER. An oily compound forming one of the components of milk, the others being curd or *caseine,* a species of sugar, and certain salts. The lighter matters suspended in milk separate in the form of cream, and this cream, by churning, becomes separated into *butter* and *butter-milk.* "During this process the temperature of the cream is slightly raised, a little oxygen absorbed, and acid produced; but this change is not essential to the separation of the butter, which takes place when air is excluded, and depends upon the rupture of the oil globules." *Brande.*

A description of the process of butter-making belongs properly to a work on rural economy, but for the sake of the simple machinery connected with it, we give a brief sketch of it. When the milk is brought into the dairy, it is strained through a fine sieve, and poured into shallow pans to the depth of four or five inches, where being exposed to a draught of cool air from opposite windows cream rapidly forms on the surface. This cream, skimmed off and churned immediately, produces the most delicate kind of butter, but it is seldom used at once, but left twenty-four hours, and then skimmed and consigned to a deep earthen jar whose contents are churned every two days. Churning is merely the beating and agitating of the cream in a wooden vessel, the simplest form of which is that of an upright wooden cask, Fig. 389, having a round lid with a hole in the centre. Through this hole a stick passes, which is four or five feet long, and has at the lower end a round flat board with holes in it. This board is a little smaller than the top of the cask, and is worked briskly up and down within it, keeping the cream violently agitated. The same purpose of keeping the cream constantly agitated is answered by the *barrel-churn,* Fig. 390, which turns on an axle by means of a common winch, and is sometimes moved by horse-power, or even by steam. The cream is strained into the churn through a cheese-cloth, which is first dipped in water and spread over the top of the churn, if it be an upright, or over the bung-hole if it be a barrel-churn. A cheese-cloth is also kept round the openings of the churn during the operation, or some of the cream will be dashed out in churning. Experience teaches

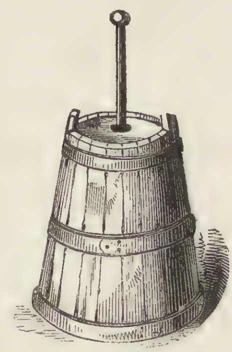


Fig. 389.

the best speed for churning, for if too quick or too slow, the butter becomes soft and frothy or strong and ill-flavoured. The butter appears first in kernels which gradually increase and conglomerate together

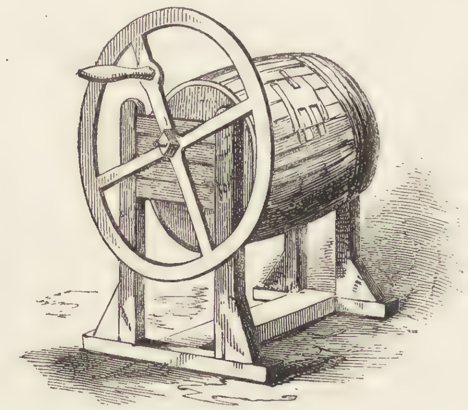


Fig. 390.

in masses: when all the butter is "come," the remaining butter-milk is set aside for the pigs, and the butter itself is repeatedly washed with spring-water in a shallow tub, and worked with the hand or with a wooden beater, or with a cheese-cloth rolled up in a ball. This working and washing is for the purpose of freeing the mass from all the remaining butter-milk. When this is perfectly accomplished, the butter is weighed out into pounds or half-pounds, and printed or rolled as may be the fashion of the district. The print is of wood, with a small air-hole in the centre. The butter is pressed down upon this pattern, shaped round the edges, and then flattened a little upon a marble or wooden slab. The print is then loosened from it by a smart blow. A large portion of butter from most considerable dairies, is however, immediately salted, and put into casks or firkins of clean white wood containing about fifty-six pounds weight. Peculiar customs in certain districts lead to varieties in the quality of butter: for instance, Devonshire butter and cream owe their celebrity not so much to the superior richness of the pastures, as to the dairy practice of that county, which differs in the following particulars. The milk, instead of being left to cream slowly in a cool place, is placed in large and deep pans, and warmed on an iron plate over a small furnace. A thick scum rises on the milk, and a little of this is removed from time to time with a spoon, to watch for the first appearance of bubbles on the surface. When these appear and before boiling begins, the milk is taken off and allowed to cool. The thick part is then removed, and is the famous clouted cream, a substance nearly as thick as butter. The butter of Epping and Cambridge is very highly esteemed in the metropolis, and that of several other counties is passed off as such. The salt butter of Holland is superior to that of any other country, and forms about three-fourths of all the foreign butter we import.

Butter is naturally of a yellow colour, and is deepened when the cows are fed in rich pastures, but an artificial colouring is also largely employed, being either the juice of carrots, or arnotto, generally the latter. [See Arnotto.] An experienced writer gives the following estimate of the quantity of butter produced by a single cow. "A good cow should produce six pounds of butter per week in summer, and half that quantity in winter, allowing from six weeks to two months for her being dry before calving—that is, 120 lbs. in twenty weeks after calving, and 80 lbs. in the remainder of the time till she goes dry,—in all about 200 lbs. in the year. If she produces more, she may be considered a superior cow, if less, she is below par. To produce this quantity the pasture must be good; and if we allow three acres to keep a cow in grass and hay for the year, which is not very far from the mark, the butter made will produce about 10*l.* at the distance of fifty miles from London, if it is sold in a fresh state, and the calf about 15*s.* at a week old. This does little more than pay rent and expenses: the profit must be made by feeding pigs, or making skim-milk cheese."

The production and consumption of butter in Great Britain is immense. The consumption in the metropolis has been averaged at 10 lbs. a-year per head, and this, with a population of 2,000,000, would give 20,000,000 lbs. or 8,928 tons. When to this is added 3,000 tons allowed to be required for the victualling of ships, &c., the total consumption, in round numbers, rises to 12,000 tons, or 26,880,000 lbs. which at 10 *d.* per lb. would be worth 1,120,000*l.*

BUTTON. An article of utility, the manufacture of which includes many curious and interesting processes. These vary greatly, according to the multiform materials used in button-making, namely, metal, horn, shell, glass, wire, mother-of-pearl, jet, precious stones, linen, velvet, satin, florentine, and embroidered stuffs of all kinds.

Birmingham is the great seat of this manufacture, which once held the foremost rank among the "toy-trades" of that busy town, and still forms an important feature in its proceedings. Hutton, in noticing the caprices of fashion with respect to this article, says: "This beautiful ornament appears with infinite variation; and though the original date is rather uncertain, yet we well remember the long coats of our grandfathers, covered with half-a-gross of high-tops, and the cloaks of our grandmothers, ornamented with a horn button nearly the size of a crown-piece, a watch, or a john-apple, curiously wrought, as having passed through the Birmingham press. Though the common round button keeps on with the steady pace of the day, yet we sometimes see the oval, the square, and the pea, the concave and the pyramid, start into existence. In some branches of traffic the wearer calls loudly for new fashions; but in this, the fashions tread upon each other, and crowd upon the wearer. The consumption of this article is astonishing; and the value in 1781 was from threepence to 140 guineas a gross. In 1818, the art of gilding buttons had arrived at such a degree of refinement, in Birmingham, that three-pennyworth of gold was made to cover a gross of buttons."

The gilt button manufacture, which thus excited Hutton's astonishment, will be the first we shall notice. Sheet-copper, with a small alloy of zinc, is the material employed. This is furnished to the button-maker in strips of the exact thickness to suit his purpose. A corner of one of these strips is placed upon a circular die or bed in a fly-press, and when the handle of the press is pulled forward, a circular cutter or punch descends, and punches out a round disc of the copper, technically called a *blank*. This being removed, the strip of copper is shifted, and another blank cut out; and so, with great rapidity, and by female hands, this process is repeated, at the rate of about thirty blanks per minute, or twelve gross in an hour. Numerous and various fly-presses

Fig. 391. PUNCHING BLANKS.

are at work at the same time, with one female to each; therefore, the total number of blanks produced in an hour is very large. This first process for gilt buttons is also common to the other varieties.

But besides the common gilt button, which is flat on both sides, there is the convex button, such as is worn by pages. To produce this, the blanks are placed one by one in a fly-press, having a concave mould and a convex punch, which, being brought down upon the soft metal, forces it into the bed, and gives it the required shape. This is also the business of women, and is performed with skill and celerity. But there are other buttons in which the convex front is closed in behind with another piece of metal, also convex on the outer surface, but less so than the front. These are called *shell* buttons. The two pieces or blanks are made separately, and brought together afterwards by the action of a die and punch, whereby the edge of the shell is bent over and lapped neatly down upon the bottom without any soldering. Metal brace-buttons, and others which have holes through them instead of a shank, are made first by stamping out the blanks, then making them a little concave in the middle with a punch at a fly-press, next piercing the holes with a punch, and then rubbing down their edges with a blunt steel tool, to prevent them from cutting the thread. To return to the simple blank: when it is cut, the edges are exceedingly sharp, and require to be smoothed and rounded. For this purpose, they are rolled between two parallel grooved pieces of steel, Fig. 392, about eighteen inches long,

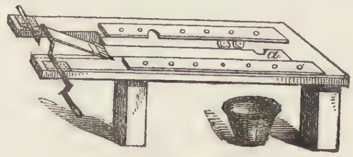


Fig. 392.

one movable, the other fixed. In each grooved piece is a semicircular opening, which, by corresponding once during each revolution of the handle, allows a blank to be dropped into the grooves, and this blank, revolving as it proceeds between the two pieces of steel, reaches a hole at *a*, and drops through into a basket beneath. This operation is carried on rapidly by a boy, who places the blanks in the cavity with one hand, while he turns the handle with the other. The blanks are now ready to be planished on the face, and this is done by placing them one by one in a die under a small stamp, and allowing them to receive a smart blow from the falling of a polished steel hammer. In this state they are ready to receive the *shanks*, or little metal loops, by which they are attached to the dress.

The manufacture of button-shanks is a distinct branch of trade at Birmingham. They are made of brass wire, and vary in weight from eight to forty gross in the pound. A coil of wire is placed in a machine, which gradually advances one end of the wire to a pair of shears, where short pieces are successively cut off. A metal finger then presses against the middle of each short piece, bending it, and at the same time forcing it between the jaws of a vice, which compress it, so as to form an eye: a small hammer then strikes the two ends, spreading them out into a flat surface, when the shank is pushed out of the machine as ready for use. Millions of shanks are made in this way in the course of a year. The office of attaching them to the blanks is assigned to women, who, while seated at a bench, adjust them in their proper position by means of a small spring clasp of iron wire, shaped like sugar-tongs, one limb of which rests on the top of the shank, the other on the face of the button. A little solder and resin are at the same time applied to the spot where the two are in contact, and this, when the buttons are afterwards placed by hundreds on iron plates in an oven, melts, and combines the two, causing them, on cooling, to be firmly united together. The button is now complete as to outward form, unless it have to be decorated with a crest or inscription; in which case a die containing the device reversed is attached with its face downwards to a heavy weight or monkey, moving between two upright posts, and suspended by a cord passing over a pulley, and ending in a stirrup-iron, into which the workman inserts his foot. On the solid bench beneath this monkey another die is firmly fixed, containing the maker's name reversed, and a hole for the shank. When the shank

is inserted in this hole, the face of the button is exposed upwards, and is ready to receive the impression from above. This is given by the workman withdrawing his foot from the stirrup, which lets the

Fig. 393. THE STAMPING PRESS.

weight descend with great force, and thus stamps the device in relief on the face of the button, while at the same time the maker's name is stamped on the back. The workman then presses on the stirrup, thus raising the weight, and quickly removes the stamped button, and with the other hand puts a plain one in its place.

The succeeding processes are ornamental, for at this stage the buttons, though perfect in shape, are exceedingly dull and ill-looking. They are first cleansed, by being stirred up in a weak solution of nitric acid; then taken out, and after draining awhile in a perforated earthen dish, dipped into a stronger acid solution; then washed and dried. They are now ready either to be silvered or gilded, as the case may be. For the former, they are put into an earthen vessel, containing a mixture of silver, common salt, cream of tartar, and some other ingredients, and well stirred up for a minute or two. This gives them a silvery white surface. For the latter, much greater care is required, in order to economise the gold. In some cases, the gilding is only to be applied to the face of the button, which is then called a *top;* in others, to the whole surface, making what is called an *all-over.* For the latter purpose, the buttons are first pickled in dilute sulphuric acid, and then immersed in a solution of nitrate of mercury, called *quick water*, which leaves a thin film of mercury over their whole surface. If tops are to be made, the buttons are not immersed, but arranged on a board (in which there are holes for the shanks), and brushed over their faces with the liquid. Owing to the astonishing divisibility of gold, five grains are sufficient to gild 144 one-inch buttons, and sometimes two-and-a-half grains are made to serve the purpose. A few grains of gold-leaf dissolved in about ten times its weight of mercury is the amalgam used in gilding. It is gently heated in an iron ladle, and stirred with an iron rod; then poured into cold water, and finally strained through wash-leather, to remove the superfluous mercury. The mass left in the leather is in a semi-fluid state: this is dissolved in dilute nitric acid, and the buttons stirred about in the solution, for all-overs, or merely brushed on the face, for tops. The buttons do not at this period present the slightest appearance of gold: they are of a dull silvery colour, due to the excess of mercury which has dissolved the gold. The next process, therefore, is to drive off all the mercury by heat, and so allow the gold to become visible. This was formerly done at great loss, both of the material and of the health of the work-people, over an open fire, but is now managed by placing the buttons in a wire cage, within a furnace, constructed to preserve and condense the fumes of the mercury, by allowing of their escape into a vessel containing water, instead of being diffused through the room and poisoning the work-people. Under the present arrangement, a woman can sit without danger and turn the handle of the cage, thus exposing all the buttons in succession to the action of the fire. From this process, which is called *drying-off*, the buttons certainly come forth of a gold colour, but it is still of a dull and unpleasing hue. To give the requisite polish which

Fig. 394. DRYING-OFF

is characteristic of a new gilt button, they are now removed to the lathe, and carefully burnished with bloodstone, which completes the process.

The gilt-button manufacture has suffered greatly on account of the prevalence of other fashions in this article. The florentine and the silk button have nearly superseded it, and these have been carefully improved from time to time, and made the subject of various patents. In one of these, the fabric for covering the buttons is expressly woven for the purpose, and contains patterns and ornamental designs placed at suitable distances for cutting up into circular pieces for covering buttons. The ground may be of satin, satinet, twill, &c., with an ornamental central figure of any fibre. The parts of a florentine button

are numerous, and the manufacture is very ingenious. All the different parts are cut out at a fly-press: they are, first, a metal shell, of which a front and side view are shown in Fig. 395, No. 1; secondly, a metal

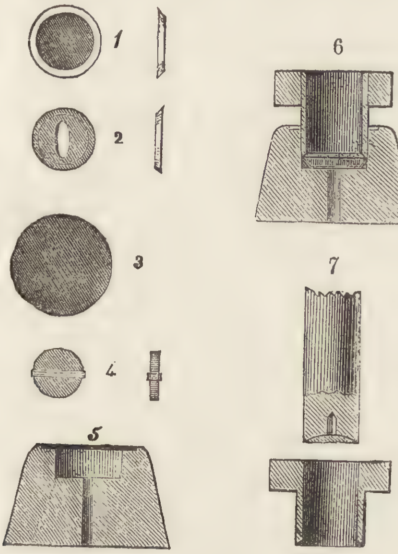


Fig. 395.

collet, with an oblong hole for the shank of the button (No. 2); thirdly, a circular piece of silk, or other woven material (No. 3); fourthly, the padding, which lies under the collet, and which has a thread wound round it, at right angles to the oblong hole of the collet (No. 4). This padding is made up of several layers of soft paper, and a layer of silk over them, the whole forming the back of the button. After all the pieces are cut out, the circular piece of silk (3) is first placed on the face of the die or mould (shown in section at No. 5); the metal shell (1) is then placed on the silk covering, and the two together are pressed down to the bottom of the die by means of a punch, which nearly fits the hollow of the die. This punch is then removed, and a hollow tool (6) forced into the die, by which the edges of the silk are forced toward the centre, thus overlapping the shell. The collet (2) with the padding (4) is then dropped into the mould through a hollow tool (7), the collet being uppermost. A punch is then pressed down within the hollow tool, forcing the padding and the edges of the outer covering of the button into the shell, which retains them with sufficient firmness until the button undergoes its final pressure. The button, thus far advanced, is removed from the die by a wire passed up through a channel made for the purpose. The final pressure is given by a punch with a plain face, the workman holding a piece of tissue-paper between the punch and the face of the button, to prevent injury to the latter. In this kind of button there is no projecting shank, but a flexible one through which the needle can be easily passed. By a recent improvement, this final pressure is given by the punch and die which are employed in covering the front shell, and bringing the parts of a button together. This is not an unimportant circumstance, though it may seem a trivial one; for, by lessening the number of processes which an article of manufacture has to go through, the cost is lessened also, and the patentee has the preference in the market, and a decided advantage over his fellow manufacturers.

CABLE. [See CHAIN-CABLE.—ROPE.]

CACAO. [See COCOA.]

CADMIUM (from *καδμεια*), a term formerly applied to calamine and to the substance which sublimes from the furnace during the manufacture of brass. Cadmium is a simple metal, and was discovered in 1817 by Stromeyer, while he was seeking to ascertain the cause of the yellow colour of certain oxides of zinc. It has since been found in several varieties of zinc ore. It resembles tin in its physical properties, but is rather harder and more tenacious: its specific gravity is 8.60, and somewhat exceeds 8.69 after hammering. It fuses at a temperature a little above that required by tin. Air scarcely acts upon it except when heated, and then it forms an orange-coloured oxide. The equivalent of cadmium is 56. This metal has not been used in the arts, except in some cases for stopping teeth.

CAFFEINE. [See COFFEE.]

CAISSON. [See BRIDGE.]

CALAMANCO, a sort of woollen stuff chequered in the warp, so that the checks are seen on one side only. [See WOOL.]

CALAMINE, a native carbonate of zinc. [See ZINC.]

CALCAREOUS EARTH, a term commonly applied to lime in any crude form.

CALCAREOUS SPAR, crystallized native carbonate of lime, of which the primitive form, as it occurs in *Iceland spar*, is an obtuse rhomboid of 105° 5′ and 74° 55′. Its specific gravity is 2.72. The secondary forms are more numerous than those of any other substance. Bournon in his *Traité de Minéralogie* has described and figured 680 modifications. [See LIME.]

CALCEDONY. [See AGATE.]

CALCINATION, a term now synonymous with *oxidizement* or *oxidation.* When metals are heated in oxygen or with access of atmospheric air, many of them lose their metallic character, and become *oxides* or *calces*, as they were formerly termed. [See METALS.]

CALCIUM, the metallic basis of lime. [See LIME.]

CALCULATING MACHINES. Mathematical calculations, from the simple processes of arithmetic, to the refined operations of algebra and geometry, enter so largely into the common concerns of life, or by their results are of such inestimable value to trade, commerce, navigation and science, and consequently more or less directly to every member of a civilized community, that any successful attempt to reduce the slow and often erroneous operations of the mind to the rapid and precise performances of a machine, must be regarded as a public benefit. But as the human mind cannot spring at once from a state of ignorance into one of knowledge; as an imperfect

condition of science cannot suddenly approach perfection; as all our knowledge and all our discoveries must be made by slow and painful steps; as the human mind requires the strong illuminating power of present knowledge, to penetrate even a short distance into the unknown and unexplored region of discovery, so we may readily suppose that the invention of a machine so truly wonderful as that contrived by Mr. Babbage, must have been the offspring of an old family of machines, professing the same object, but accomplishing far less. That this is so, detracts nothing from the last inventor, for had there been no other calculating machines previous to his, he could have gained nothing from the experience of the past, and consequently his machine, instead of being almost perfect, might have been only a germ for future men of genius to improve upon. But not only machines, but mental processes which give birth to machines, pass through various phases of improvement in the course of ages. There was a time when our forefathers could perform the arithmetical operation of addition, but not that of multiplication. It was discovered, however, that without greatly changing the character of addition, its processes might be facilitated by arranging and committing to memory a sort of table in which the results of addition are presented for the combinations of units from 1 to 12. Thus when we multiply 9 by 6, we add up 9 six times; but in the table we lose sight of the process of addition, and simply take the result as it stands, $9 \times 6 = 54$. In like manner division was introduced as a speedier method of subtraction; for if we have to divide 30 by 5, we in effect subtract 5 from 30 six times over, by which we separate 30 into six parcels of 5 each.

One of the simplest forms of calculating machines, is the *Abacus*. The school-boys of ancient Greece acquired the elements of knowledge by working on a smooth board with a narrow rim, called the *Abax*, probably from the combination of Α, Β, Γ, the first letters of their alphabet. They were instructed to compute by forming progressive rows of counters, which consisted of small pebbles, of round bits of bone or ivory, or even of silver coins. The same board also served for teaching the rudiments of writing and the principles of geometry, for by strewing the abax with sand, it was easy with a small rod to trace letters, draw lines, construct triangles, or describe circles. It appears also, that the practice of bestowing on pebbles an artificial value, according to the rank or place which they occupied, was practised at a very early period, for Diogenes Laertius states that Solon used to compare the passive ministers of kings or tyrants, to the counters or pebbles of arithmeticians, which are sometimes most important, and at other times quite insignificant. The Romans borrowed their abacus from the Greeks, and to each pebble or counter used on the board, they gave the name of *calculus*, the diminutive of *calx*, a stone; and applied the verb *calculare* to the operations performed with such pebbles; whence the English verb to calculate. (The Greeks also derived their verb, ψηφίζειν, to compute, from ψῆφος, a pebble.) A small box or coffer, called a *loculus*, with compartments for holding the counters, was a necessary appendage of the abacus: so that, "instead of carrying a slate and satchel, as in modern times, the Roman boy was accustomed to trudge to school, loaded with his arithmetical board, and his box of counters."[1] The abacus appears to have been divided by means of perpendicular lines or bars: this was improved by dividing the surface of the board by sets of parallel grooves, or by stretched wires, or even by successive rows of holes. It was easy to move small counters in the grooves, to slide perforated beads along the wires, or to stick large nobs in the different holes. To diminish the number of marks required, each column was surmounted by a shorter one, wherein each counter had the same value as five of the ordinary kind, being half the index of the denary scale. Two of these instruments, delineated on the antique monuments, show clearly how they were used. In one the numbers are represented by flattish perforated beads, ranged on parallel wires; and in the other they are expressed by small round counters, moving in parallel grooves. These instruments contain each seven principal bars, expressing in order units, tens, hundreds, thousands, ten-thousands, hundred-thousands, and millions; and above them are shorter bars, following the same progression, but having five times the relative value. With four beads on each of the long wires, and one bead on every corresponding short wire, any number as far as ten millions could be expressed. Immediately below the place of units is a bar with its corresponding branch, both intended to signify ounces, or the twelfth parts of a pound. Fractions of ounces are also expressed by three very short bars behind the rest.

During the middle ages, calculations were performed on the principle of the abacus, by representing numbers by counters placed in parallel rows. It was the usual practice for merchants, auditors of accounts, or judges appointed to decide in matters of revenue, to appear on a covered bank or bench; before them was a table covered with a cloth, resembling the abacus, and distinguished by perpendicular and *chequered* lines. The Court of Exchequer, which takes cognisance of all questions of revenue, was introduced at the Norman Conquest. A writer of the twelfth century describes this table or *scaccarium* as being about ten feet long and five broad, with a ledge or border about four inches high, to prevent anything from rolling over, and was surrounded on all sides by seats for the judges, the tellers, and other officers. It was covered every year after Easter Term with fresh black cloth, divided by perpendicular white lines, at intervals of about a foot, and again parted by similar transverse lines. Small coins were used for counters: the lowest bar exhibited pence, the one above it shillings, the next pounds; and the higher bars denoted successively tens, twenties, hundreds, thousands, and ten-thousands of pounds. The first bar, therefore, advanced by dozens, the second and

(1) Encyclopædia Britannica, Art. *Abacus*.

third by scores, and the rest by multiples of ten. The teller sat about the middle of the table: on his right hand eleven pennies were heaped on the first bar, and a pile of nineteen shillings on the second; while a quantity of pounds was collected opposite to him on the third bar. For the sake of expedition, he might employ a different mark to represent half the value of any bar; a silver penny for ten shillings, and a gold penny for ten pounds.

Offices for changing money were indicated by a chequered board, a sign afterwards adopted for an inn or hostelry.

The method of recording numbers by tallies was also introduced into England at the Norman Conquest. Tallies are well seasoned sticks of hazel or willow, Fig. 396, from the French *tailler*, to cut, because they are cut or squared at each end. The sum of money was marked on the side with notches by the cutter of tallies, and also inscribed on both sides in Roman characters by the writer of tallies. The smallest notch denoted a penny, a larger one a shilling, and one still larger a pound: other notches increasing in breadth denoted a ten, a hundred, and a thousand. The stick was then cleft through the middle by the

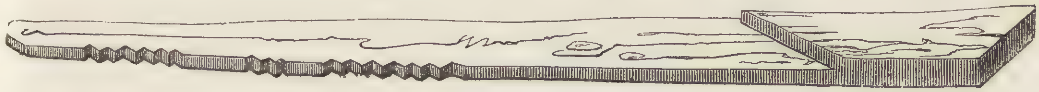


Fig. 396. EXCHEQUER TALLY.

deputy-chamberlains with a knife and a mallet: the one portion being called the *tally*, and the other the *countertally*.

The Chinese make use of an ancient instrument called the *Schwan-pan*, or *computing-table*, which is similar in shape and construction to the abacus of the Romans. It consists of a small oblong board surrounded by a high ledge, and parted lengthwise near the top by another ledge. It is divided vertically by 10 smooth and slender rods of bamboo, on which are strung 2 small balls of ivory or bone in the upper compartment, and five such balls in the lower and larger compartment: each of the latter on the several bars denoting a unit, and each of the former a 5. As the decimal notation is used in China, this instrument is well adapted for facilitating calculation, and the native traders are said to use it with such rapidity and skill as to astonish Europeans.

The Chinese also make use of digital signs for denoting numbers, (as did also the ancient Romans, whence the term *digit* from *digitus* a finger.) As every finger has 3 joints, let the thumb nail of the other hand touch those joints in succession, passing up the one side of the finger, down the middle and again up the other side, and it will give 9 different marks applicable to the denary scale of arrangement. On the little finger those marks signify units, on the next finger tens, on the middle finger hundreds, on the index finger thousands, and on the thumb hundred thousands. With the combined positions of the joints of one hand therefore it is easy to advance by signs as far as a million. The merchants of China are said to conclude bargains with each other by means of these signs, and that often with a fraudulent design they conceal them from the by-standers, by seeming only to seize each others' hands with a hearty grasp.

A simple form of arithmetical machine was invented by Baron Napier of Merchiston, the inventor of logarithms. It is called *Napier's bones* or *rods*. It consists of a number of rods or square parallelopipeds 3 inches in length and $\frac{3}{10}$ths of an inch in breadth, Fig. 397. Each of the faces of the parallelopipeds except the *index-rod* on the left hand is divided into 10 equal squares, which are cut diagonally by a line from right to left downwards. In each square is inserted the product of two significant figures, so that the whole when placed together forms the

1	1	2	3	4	5	6	7	8	9	0
2	/2	/4	/6	/8	1/0	1/2	1/4	1/6	1/8	/0
3	/3	/6	/9	1/2	1/5	1/8	2/1	2/4	2/7	/0
4	/4	/8	1/2	1/6	2/0	2/4	2/8	3/2	3/6	/0
5	/5	1/0	1/5	2/0	2/5	3/0	3/5	4/0	4/5	/0
6	/6	1/2	1/8	2/4	3/0	3/6	4/2	4/8	5/4	/0
7	/7	1/4	2/1	2/8	3/5	4/2	4/9	5/6	6/3	/0
8	/8	1/6	2/4	3/2	4/0	4/8	5/6	6/4	7/2	/0
9	/9	1/8	2/7	3/6	4/5	5/4	6/3	7/2	8/1	/0

Fig. 397.

common multiplication table; the only difference being that the right hand or unit figure of the product is placed below the diagonal line, and the 10 belonging to it above it; and when the product is but one figure, it is written below it. With these rods, multiplication and division can be performed by means of addition and subtraction; but as the same figure may occur several times, it is necessary to be provided with 3 or 4 rods of each kind, and to have 4 sides of each rod inscribed with a different set of figures. Multiplication is performed by placing the rods so as to form the multiplicand at the top; then apply a rod with unity at the top to the left hand side, and exactly opposite to each figure will be found the product arising from the multiplication of that figure into the multiplicand; but this must be obtained by addition, in the following manner:—the figure below the diagonal on the right-hand rod, is the unit figure of the product; the figure above the diagonal, added to the figure on the next rod below the diagonal, gives the next figure of the product; the figure above the diagonal on the second rod, added to the figure below the diagonal on the following rod, gives the third figure of the product; and so on. It will not be necessary to illustrate the use of these rods by examples, for the multiplication

table is so well and so generally known, as to render the tedious use of Napier's rods unnecessary. The method of performing division therewith, is even more complex than that of multiplication.

Many other contrivances for facilitating calculation have been made from time to time, but they take the place of *instruments* rather than of *machines*. The first calculating machines properly so called are those by Gersten and Pascal, the former of which is described by Professor Gersten himself, in an early number of the *Philosophical Transactions*, and the latter is described by Diderot in the *Encyclopédie Méthodique*. Article *Arithmétique*.

It would not be possible to describe these machines without the aid of elaborate engravings. Their use, if indeed they were ever used practically, was confined to a few simple arithmetical operations, which can be performed much more readily by the pen of a skilful computer. It will, however, be useful to notice the principle upon which these machines were constructed, since it is that which has been subsequently adopted in later and more efficient machines of this class. If we notice the manner in which quantities are combined in the common system of numeration, it will be found that the value of each figure is ten times greater than it would be if it occupied a position one place to the right. Thus, in the number 1829, although 9 is greater than 2, yet the 2 in this position represents a larger sum than the 9, because it occupies a place to the left of the 9. The quantities really expressed by the figures 1829 are $\left\{\begin{matrix}1000\\800\\20\\9\end{matrix}\right\}$, but in practice we omit the cyphers, and place the significant figures side by side preserving their proper position from the right hand. Now if we have a wheel on whose axis is a pinion with leaves or teeth; if these teeth work into another set of teeth or cogs on the periphery of another wheel, and if the teeth on the latter wheel are just ten times as numerous as those on the pinion, this system being made to revolve, the pinioned wheel will revolve just ten times as fast as the other. This produces a kind of analogy between the decimal notation and the working of the wheels; for it takes 10 units to make up 1 figure or unit in the second place in common numeration, and it requires 10 revolutions of the pinioned wheel to impart 1 revolution to the larger wheel. This is the fundamental principle in the calculating machines now under notice. In such machines there are a number of dial-faces, each marked with figures from 1 to 10. These dial-faces are fixed upon wheels, the teeth of which work into the pinions of other wheels, on which are similarly divided faces or discs, so that while one face indicates units, another indicates tens, a third, hundreds, and so on. These wheels and dial-faces may be differently arranged in different machines, but the principle is the same in all. In Gersten's instrument, for example, if 32 were to be added to 59, two dial-faces had to be turned by hand until two needles pointed to the two figures 5 and 9, one on each plate: two slides were then adjusted, until two indices pointed to the figures 3 and 2, one on each slide. Both the discs and both the slides were connected with toothed rack-work, which working into each other, turned another dial-plate in such a direction as to show on its face 91, or the sum of 32 and 59. If on the contrary it were required to subtract 59 from 91, indices would be pointed to 9 and 1 on two separate discs, and to 5 and 9 on two separates slides, and the movement of these discs and slides in an opposite direction to the former would turn another wheel, to show 32 on its face, the difference between 59 and 91. The process of multiplication was effected by a kind of reiteration of additions, and that of division by a succession of subtractions.

Pascal's machine was constructed for the purpose of performing certain calculations connected with the duties of an office, held in Upper Normandy by Pascal's father. The calculations were reckoned in the currency of France at the time: the *denier* wheel had 12 teeth, representing the number of deniers in a *sol;* the sol wheel had 20 teeth, equal to the number of sols in a livre, above which each wheel had 10 teeth, indicating 10, 100, 1000, &c. livres. Connected with the wheels were a number of cylinders. The cylinder expressing deniers had the following figures engraved upon it:—

0. 11. 10. 9. 8. 7. 6. 5. 4. 3. 2. 1.
11. 0. 1. 2. 3. 4. 5. 6. 7. 8. 9. 10.

The cylinder representing the sols:—

0. 19. 18. 17. 16. 15. 14. 13. 12. 11. 10. 9. 8. 7. 6. 5. 4. 3. 2. 1.
19. 0. 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18.

And when it expressed the units of the livres or pounds:—

0. 9. 8. 7. 6. 5. 4. 3. 2. 1.
9. 0. 1. 2. 3. 4. 5. 6. 7. 8.

Now as matters are so arranged in this machine that a complete turn of the first barrel is necessary to produce a twentieth of the second; a turn of the second to produce a tenth of the third; a turn of the third to produce a tenth of the fourth; and in short, since the barrels follow in their revolutions the proportion which prevails between the different orders of the figures in arithmetic, it is evident that the operations of numbers may be performed by means of the barrels and the figures which are engraved on them.

This machine has some ingenious arrangements which we cannot stay to describe: it is, however, tedious in its operations and inferior to the common modes of performing arithmetical calculations. It is introduced here in order to furnish a glimpse of one of the predecessors of Mr. Babbage's machine. It was improved by M. de l'Epine in 1725, and again in 1730 by M. Boitissendeau. Both machines are described in the "Recueil des Machines approuvées." About 1670, Sir Samuel Morland contrived two machines, one for addition and subtraction, and the other for multiplication, division, and the extraction of the square and cube roots. They are described in the Philosophical Transactions, No. 94. Leibnitz

is also said to have invented a calculating machine, but no account of it appears to have been published.

But machines of this kind, however ingenious, were not directed to the supply of a want which had long been really felt; namely, the production of arithmetical and other tables which should be rigorously correct. In the navigation of a ship, in the preparation of an almanac, in the higher branches of astronomy, and in other occupations, the use of such tables is very great. As such tables are constructed by human heads and hands, they are all more or less disfigured by errors. Tables of multiplication, of powers and roots, of trigonometrical elements, of logarithms, of the solar, lunar, and planetary motions, &c., have been computed and published in various countries, to the extent of many hundred volumes; and although very great care has been bestowed on their preparation, they all contain errors of greater or less magnitude. In a multiplication table (as far as 100 times 1,000) constructed by Dr. Hutton for the Board of Longitude, 40 errors were discovered in a single page taken at random. In the solar and lunar tables from whence the computations were formerly made for the Nautical Almanac, more than 500 errors were discovered by one person. In the "Tables requisite to be used with the Nautical Almanac," more than 1,000 errors were detected. In certain tables published by the Board of Longitude, a table of errata, containing 1,100 errors, was affixed. It was afterwards found necessary to have a list of errata of the errata; and in one instance there was an erratum of the errata of the errata.

In cases such as these the sources of error are so numerous that it is difficult to find a remedy for them all, so long as the common modes of calculating, transcribing, and printing are adopted. Some of these errors have been referred to false computation, others to inaccurate transcription; some have been referred to the compositor; others to a displacement of the types by the inking-ball used in the old method of printing, and the incorrect replacement of such types by the pressman.

The apparently hopeless task of preparing accurate tables by the common methods led Mr. Babbage, about thirty years ago, to consider whether a machine might not be constructed for computing and printing off mathematical tables. The proposed machine was to be capable not only of performing arithmetical calculations, but all those of mathematical analysis, provided their laws were known; and the principle upon which it was to depend was to be of so general a nature that, if applied to machinery, the latter might be capable of mechanically translating the operations indicated to it by algebraical notation.

Mr. Babbage's first attempts originated in the following circumstances. The French government, wishing to promote the extension of the decimal system, had ordered the construction of logarithmical and trigonometrical tables of enormous extent. M. de Prony, who directed the undertaking, divided it into three sections, to each of which was appointed a special class of persons. In the first section, the formulæ were so combined as to adapt them to the purposes of numerical calculation; in the second, these same formulæ were calculated for values of the variable, selected at certain successive distances; and under the third section, comprising about 80 individuals, who were most of them only acquainted with the first two rules of arithmetic, the values which were intermediate to those of the second section were interpolated by means of simple additions and subtractions. The body of tables thus calculated consisted of 17 MS. folio volumes. They have not been published. The printing was begun, and a small portion stereotyped; but a sudden fall in the value of assignats rendered it impossible for the printer to fulfil his contract with the government. The British government made an offer of 5,000*l.* towards the completion of the work; but political circumstances appear to have prevented its re-adoption, and it has never been resumed. A similar undertaking was, however, entered upon in England; and Mr. Babbage conceived that the operations performed under the third section might be executed by a machine, which he proposed to call the *Difference Engine*, on account of the principle upon which its construction is founded. Some notion of this will be gained by considering the series of whole square numbers,

1, 4, 9, 16, 25, 36, 49, 64, &c.

By subtracting each of these from the succeeding one, a new series is obtained, named the series of first differences, consisting of the numbers,

3, 5, 7, 9, 11, 13, 15, &c.

On subtracting from each of these the preceding one, we obtain the second differences, which are all constant, and equal to 2. This succession of operations and their results are represented in the following table:—

	A. Column of Square Numbers.	B. First Differences.	C. Second Differences.
	1		
		3	
	4		2 *b*
		5	
a	9		2 *d*
		7	
c	16		2
		9	
	25		2
		11	
	36		⋮

From the mode in which the columns B and C have been formed, it is obvious that if we wish to pass from the number 5 to the succeeding one 7, for example, we must add to the former the constant difference 2; so, also, if from the square number 9 we would pass to the following one, 16, we must add to the former the difference 7, which difference is, in other words, the preceding difference 5 plus the constant difference 2; or, what is the same thing, to obtain 16, we have only to add together the three numbers, 2, 5, 9, placed obliquely in the direction

a b. So also we get the number 25, by summing up the three numbers placed in the oblique direction *d c*. Commencing by the addition 2 + 7, we have the first difference 9 consecutively to 7; adding 16 to 9, we have the square 25. Thus, the three numbers 2, 5, 9, being given, the whole series of successive square numbers, and also that of their first differences, may be obtained by means of simple additions.

Now, to reproduce these operations by means of a machine, suppose the latter to have three dials, A, B, C, on each of which are traced, say, 1,000 divisions, over which a needle shall pass; that the two dials C, B, have also a registering hammer, which is to give a number of strokes equal to that of the divisions indicated by the needle; that for each stroke of the registering hammer of the dial C, the needle B shall advance one division, and that similarly the needle A shall advance one division for every stroke of the registering hammer of the dial B. Such is the general disposition of the mechanism.

This being understood, suppose, at the beginning of the operations which are to be executed, we place the needle C on the division 2, the needle B on the division 5, and the needle A on the division 9. Allow the hammer of the dial C to strike: it will strike twice, and at the same time the needle B will pass over two divisions. The latter will then indicate the number 7, which succeeds the number 5 in the column of first differences. If the hammer of the dial B be then allowed to strike, it will strike 7 times, during which the needle A will advance 7 divisions: these added to the 9 already marked by it will give the number 16, which is the square of the number consecutive to 9. If we now recommence these operations, beginning with the needle C, which is always to be left on the division 2, it will be seen that, by repeating them indefinitely, we may successively reproduce the series of whole square numbers by means of very simple mechanism. It would be quite impossible, however, to enter upon the details of the machinery, for the drawings of the various parts, constructed by Mr. Babbage, or under his direction, cover a space of 1,000 square feet.

A most valuable feature intended to be introduced into this machine is the power of printing the tables as fast as it calculates them. This was proposed to be accomplished in the following manner:—When one of the dial wheels is in such a position as to indicate any particular figure of the table, some mechanism at the back raises a curved arm, containing several figure punches. A plate of copper is brought near the bent arm, and by a sudden blow an impression of the required figure is punched in the copper, and the figure so punched corresponds with that indicated on the dial. The plate is shifted from place to place, until it is punched all over with figures arranged in a tabular form. It is then used either as an engraved copper plate, and printed from in that form, or it may be used as a mould in the casting of stereotype plates of the tables, which may thus be multiplied in a permanent form without the slightest chance of an erratum being required.

A portion only of this machine has been completed; but this portion is capable of calculating to five figures and two orders of differences, and performs its work with absolute precision; but no portion of the printing machinery exists.

In 1843 an application was made to Government by the Trustees of King's College, London, to allow the engine as it existed to be removed to the museum of that institution. The request was complied with, and the engine enclosed within a glass case now stands nearly in the centre of the museum. Fig. 398, is a representation thereof, made from a drawing from the engine itself.

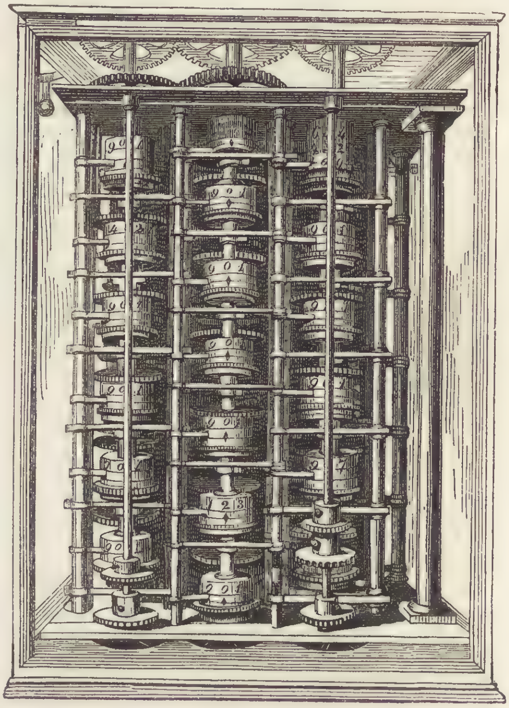


Fig. 398. BABBAGE'S CALCULATING MACHINE.—THE DIFFERENCE-ENGINE.

As this fragment of the difference-engine is public property, it will be interesting to state briefly the circumstances which have interfered with the completion of this great work of genius; and this we are enabled to do with the assistance of a chapter contained in the second Volume of Mr. Weld's "History of the Royal Society," (8vo. London, 1848,) which we understand received the sanction of Mr. Babbage himself, as a true and impartial statement.

It appears that on the 3d July, 1822, Mr. Babbage, in a letter to Sir Humphrey Davy, gave some account of a small model of his engine for calculating differences, which "produced figures at the rate of 44 a minute, and performed with rapidity and precision all those calculations for which it was designed. . . . . Induced by a conviction," says Mr. Babbage, "of the great utility of such engines, to withdraw for some time my attention from a subject on which it has been engaged during several years, and which possesses charms of a higher order, I have now

arrived at a point where success is no longer doubtful. It must, however, be attained at a very considerable expense, which would not probably be replaced by the works it might produce for a long period of time, and which is an undertaking I should feel unwilling to commence, as altogether foreign to my habits and pursuits."

Early in April 1823, the Royal Society was requested by Government to take into consideration a plan which had been submitted by Mr. Babbage, for "applying machinery to the purposes of calculating and printing mathematical tables." A committee was accordingly appointed, and on the 1st May they reported, "that it appears that Mr. Babbage has displayed great talents and ingenuity in the construction of his machine for computation, which the Committee think fully adequate to the attainment of the objects proposed by the inventor, and that they consider Mr. Babbage as highly deserving of public encouragement in the prosecution of his arduous undertaking."

In consequence of this Report, the Lords of the Treasury directed the issue of 1,500*l.* to Mr. Babbage, to enable him to bring his invention to perfection. "Towards the end of July 1823, Mr. Babbage took measures for the construction of the present difference-engine, and it was regularly proceeded with for four years. And here it is right to state, that Mr. Babbage gave his mental labour gratuitously, and that from first to last he has not derived any emolument whatever from Government. Sectional and other drawings of the most delicate nature had to be made; tools to be formed expressly to meet mechanical difficulties; and workmen to be educated in the practical knowledge necessary in the construction of the machine. The mechanical department was placed under the management of Mr. Clement, a draughtsman of great ability, and a practical mechanic of the highest order. Money was advanced from time to time by the Treasury, the accounts furnished by the engineer undergoing the examination of auditors, and passing through the hands of Mr. Babbage. Thus years elapsed, and public attention became at length directed to the fact, that a large sum had been expended upon the construction of the engine which was not completed." In December 1828, Government requested the Council of the Royal Society to inquire into the state of the machine. A committee was accordingly appointed, and in their report they stated, that "the progress made was as great as could be expected, considering the numerous difficulties to be overcome, and that they had no hesitation in giving it as their opinion, that the engine was likely to fulfil the expectations entertained of it by its inventor." They further stated, that the public utility of the engine must be "obvious to all who consider the immense advantage of accurate numerical tables in all matters of calculation, which it is professedly the object of the engine to calculate and print with perfect accuracy."

This report was acted on by Government; funds were advanced, the machinery was declared national property, and the works were continued for a time; but the official payments soon failed to meet the expenses incurred. Accordingly a meeting of some of Mr. Babbage's personal friends took place on the 12th May, 1829, who drew up a report in which it was stated, "that Mr. Babbage's actual expenditure has amounted to nearly 7,000*l.*, and that the whole sum advanced to him by the Government is 3,000*l.* This report being submitted to Government, a further grant of 3,000*l.* was made towards the completion of the machine. Difficulties, however, of another kind arose. The engineer's bills to December 1830, amounting to nearly 7,200*l.*, had been delivered in such a state that it was impossible to decide how far the charges were just and reasonable. Mr. Maudslay, one of the engineers appointed by Government to examine Mr. Clement's bills, had been unable from illness to report thereon. An advance of 600*l.* was required to prevent Mr. Clement from discharging some workmen for want of funds. This was represented by Mr. Babbage to the Chancellor of the Exchequer, and it was also suggested, that as additional space was required for the erection of the machine, whether it would not contribute to its speed in completion and also to economy in expenditure, to remove the works to the neighbourhood of Mr. Babbage's own residence.

A committee of the Royal Society was again appointed to consider and report on these proposals. The Committee met Mr. Babbage at No. 21, Prospect Place, Lambeth, where the construction of the engine was carried on, and minutely inspected the machinery and drawings. The report stated that the various parts of the machine had been executed with the greatest possible degree of perfection, and that the pains taken to verify the charges on the part of the Government were altogether satisfactory. It was also recommended that the machinery and drawings be removed into fire-proof buildings without delay. A plot of ground held on lease by Mr. Babbage, adjacent to his garden at the back of his house in Dorset Street, was recommended as a desirable site for the contemplated buildings, of which the plans and erections had been submitted to the Committee. Mr. Brunel estimated that 8,000*l.* would be sufficient to defray the expenses, but he advised the sum of 12,000*l.* to be provided by way of estimate, and thought that the yearly sum required, exclusive of the sum requisite for the buildings and removal (say 2,000*l.*) would not exceed from 2,000*l.* to 2,500*l.*

This estimate was approved by a committee of practical engineers appointed by Government, and the recommendations were adopted. A fire-proof building was erected on the proposed site. New difficulties, however, arose. "When about 17,000*l.* had been expended, further progress was arrested on account of a misunderstanding with Mr. Clement, who made the most extravagant demands as compensation for carrying on the construction of the engine in the new buildings. These demands could not be satisfied with proper regard to the justice due to Government. Mr. Clement accordingly withdrew from the under-

taking, and carried with him all the valuable tools that had been used in the work; a proceeding the more unfortunate, as many of them had been invented expressly to meet the unusual forms and combinations arising out of the novel construction.[1] An offer was made to surrender the tools for a given sum, which was declined, and the works came to a stand-still.

During the suspension of the works, Mr. Babbage had been deprived of the use of his own drawings. In the meantime, however, having again considered the general principles on which machinery for calculation might be constructed, a principle of an entirely new kind occurred to him, the power of which over the most complicated arithmetical operations seemed almost unbounded. This was the executing of analytical operations by means of an *analytical engine.* In May 1835, Mr. Babbage, writing to M. Quetelet, says that for six months he had been engaged in making the drawings of a new calculating machine, of far greater power than the first. "I am myself astonished," says Mr. Babbage, "at the power I have been enabled to give this machine: a year ago, I should not have believed this result possible. This machine is intended to contain a hundred variables, or numbers susceptible of changing; and each of these numbers may consist of twenty-five figures. The greatest difficulties of the invention have already been surmounted, and the plans will be finished in a few months."

In a visit to Turin, Mr. Babbage explained to Baron Plana, M. Menabrea, and others, the mathematical principles of his analytical engine, and also the drawings and engravings of the contrivances by which those principles were to be carried out. M. Menabrea, with Mr. Babbage's consent, drew up an account of the analytical engine, which he published in the 41st volume of the *Bibliothèque Universelle de Genève.* An English translation, with copious original notes, made by Lady Lovelace, was published in the 3d volume of Taylor's *Scientific Memoirs,* (London, 1843.) From these notes the following passage is selected:—

"The distinctive characteristic of the Analytical Engine, and that which has rendered it possible to endow mechanism with such extensive faculties as bid fair to make this engine the executive right hand of abstract algebra, is the introduction into it of the principle which Jacquard devised for regulating, by means of punched cards, the most complicated patterns in the fabrication of brocaded stuffs. It is in this that the distinction between the two engines lies. Nothing of the sort exists in the Difference Engine. We may say most aptly that the Analytical Engine weaves algebraical patterns, just as the Jacquard loom weaves flowers and leaves. Here, it seems to us, resides much more of originality than the Difference Engine can be fairly entitled to claim. We do not wish to deny to this latter all such claims. We believe that it is the only proposal or attempt ever made to construct a calculating machine founded on the principle of successive orders of differences, and capable of printing off its own results; and that this engine surpasses its predecessors, both in the extent of the calculations which it can perform, in the facility, certainty, and accuracy with which it can effect them, and in the absence of all necessity for the intervention of human intelligence during the performance of its calculations. Its nature is, however, limited to the strictly arithmetical, and it is far from being the first or only scheme for constructing arithmetical calculating machines with more or less of success."

The state of the Analytical Engine at the time when Mr. Weld wrote his account (1848) was as follows:—"Mechanical notations have been made, both of the actions of detached parts and of the general action of the whole, which cover about four or five hundred large folio sheets of paper. The original rough sketches are contained in about five volumes. There are upwards of one hundred large drawings. No part of the construction of the Analytical Engine has yet been commenced. A long series of experiments have, however, been made upon the art of shaping metals; and the tools to be employed for that purpose have been discussed, and many drawings of them prepared. The great object of these inquiries and experiments is, on the one hand, by simplifying the construction as much as possible, and on the other, by contriving new and cheaper means of execution, ultimately to reduce the expense within those limits which a private individual may command."

Repeated applications to Government on the part of Mr. Babbage produced only this result:—that Government abandoned all further interference and assistance in the matter, and at the same time withdrew all claim to the machine as at present constructed, and it was placed at the entire disposal of Mr. Babbage. Considering, however, that the drawings and the parts of the machine already executed were paid for by the public money, Mr. Babbage declined to accept the offer; and it is greatly to be deplored that no further steps have been taken to carry out a scheme, the completion of which must be regarded as one of the glorious results of peaceful progress.

The reader who is desirous of further information on this subject will do well to consult the volume of Taylor's Scientific Memoirs already referred to. The accomplished author of the translation of M. Menabrea's memoir has given a list of most of the printed documents connected with the subject, up to the year 1843.

CALENDERING. A term said to be corrupted from *cylindering,* and signifying the finishing process in the manufacture of cotton or linen goods, by which they are passed between *cylinders* or rollers, and made of a level and uniform surface. When such goods

(1) Mr. Weld remarks, that Mr. Clement had a legal right to the tools. "Startling as it may appear to the unprofessional reader, it is nevertheless the fact, that engineers and mechanics possess the right of property to all tools that they have constructed, although the cost of construction has been defrayed by their employers."

have been bleached and washed, they are generally entangled and twisted, so as to be unfit for passing at once between the cylinders; they are therefore passed over the surface of a water cistern, kept constantly full, and as they thus make their way to the rollers, they unfold and accommodate themselves to the water, and are prepared as effectually as if by hand. But the action of the first pair of rollers does not spread or smooth the cloth effectually, neither does it dry it: it has, therefore, to be pulled out breadthwise, and the edges knocked against a smooth beating-stock. Pieces are also stitched together by a sailors' needle, to prepare them for the mangle. The domestic mangle will be noticed presently, but that used for calendering does not at all resemble it. It consists of a number of rollers, fixed in a strong upright frame; the rollers being forced together by levers, to which a considerable weight is attached, or by means of screws, as in Fig. 401. In some mangles the bottom rollers are grooved, the grooves gradually spreading from the right to the left on either side. The effect of this is to remove creases, by spreading out and extending the cloth as it passes between them. Above these are three smooth rollers, two of wood and one of brass, in passing between which the surface is equalized, and the cloth stretched. It is then wound upon a roller, ready to be starched.

The starch used in calendering is made from flour, deprived of gluten by fermentation in water, in the proportion of a pound of flour to a gallon of water. The whole is passed through a sieve after fermentation, and this separates the bran. The flour is then boiled, and a small quantity of indigo added, to give it a blue colour, after which more water is added, according to the degree of stiffness to be given to the goods. This liquid is frequently thickened with porcelain clay, or calcined plaster of Paris, or both, in order to give an appearance of strength and thickness to the cloth. This all disappears as soon as the goods are washed; therefore it merely makes them more attractive to the eye of the purchaser. The practice was originally deceptive; but it can scarcely be called so now that it is generally adopted, and is perfectly well known to the great majority of buyers.

The method of applying the starch is by a stiffening mangle, formed of rollers of brass and wood pressed together by levers, the pressure being regulated by the quantity of starch required to be left in the material. The starch is contained in a trough, into which a roller dips, and the cloth in passing under this roller becomes filled with starch, the superfluous part of which is pressed out again by the upper rollers and falls back into the trough. The next operation is drying, which in the more substantial goods is effected by passing the goods over large tinned iron or copper cylinders, Fig. 399, heated by being filled with steam; but for muslins, the process merely consists of stretching out the material on long frames in a warm room. This is done with such celerity, that two young women can stretch a piece twenty-five yards long, and fasten it to the frame by pressing down numerous clamps prepared for that purpose, in the space of two minutes. The piece is from ten to fifteen minutes in drying, and is then transferred to the making-up room. But in some cases it receives on the frames, what

Fig. 399. DRYING CYLINDERS.

is called the *patent finish;* that is, as soon as it is stretched, the two long sides of the frame are made to work backwards and forwards in opposite directions, giving the muslin a diagonal motion, which is continued till it is quite dry. The effect of this is to remove the harsh and stiff appearance which the starch would otherwise produce, and to make the muslin very clear and elastic. It has in fact the same effect as the beating and clapping of muslin articles by the laundress, in what is called clear-starching.

The finish for cotton goods often consists of a glazing, which is distinctively and especially known as calendering, and which gives a bright and beautiful gloss to the material. But this must first be damped

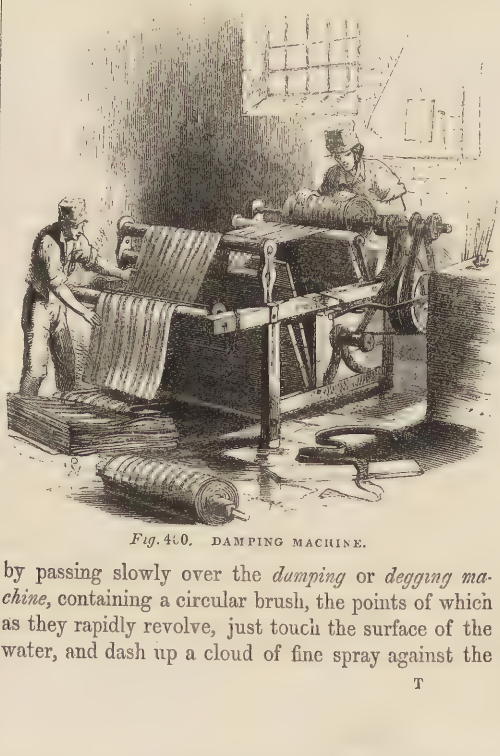


Fig. 400. DAMPING MACHINE.

by passing slowly over the *damping* or *degging machine,* containing a circular brush, the points of which as they rapidly revolve, just touch the surface of the water, and dash up a cloud of fine spray against the

cloth. This being completed and the whole of the cloth uniformly damped, it now passes to the calendering machine, a number of rollers contained in a massive frame-work. The rollers are connected with a long lever loaded with weights at the further extremity, by which, or by means of screws as in Fig. 401, almost any amount of force may be obtained, and the surface texture of the cloth varied at pleasure. With considerable pressure between smooth rollers, a soft and silky lustre is given by the equal flattening of all the threads. By passing two folds at the same time between the rollers, the threads of one make an impression on the other, and give a wiry appearance with hollows between the

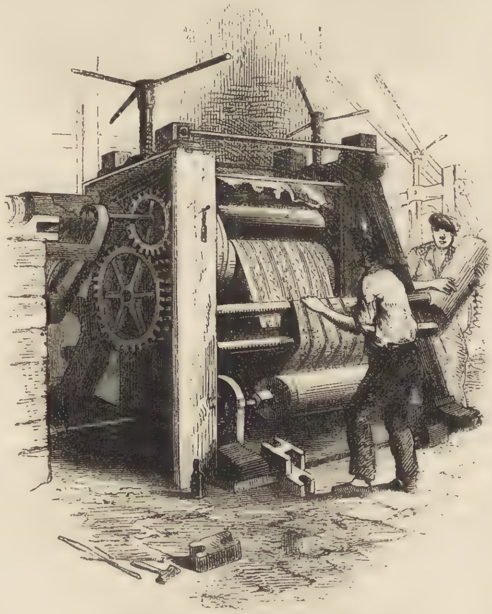


Fig. 401. CALENDERING MACHINE.

threads. This may be varied at pleasure. It will be taken for granted by those who have never witnessed the operations, that the rollers are all of iron but this is not the case; they are of cast-iron, wood, paper, or calico, according to the uses for which they are designed. Great care is taken in the construction of the rollers, whatever the material, and those of paper are far from being so fragile as the nature of the substance would seem to imply, for they are in fact a mass of circular disks of pasteboard, threaded upon a square bar of wrought iron, and secured by iron disks at each end. These disks are screwed down tightly together, making a solid cylinder, which is placed in a stove and kept at a high temperature for several days to drive off all moisture, when the screws are tightened and the cylinder becomes remarkably dense and hard, so much so that, in being finished at a turning-lathe, it blunts all the tools employed, and requires two men to be kept constantly at work sharpening them. Copper embossed rollers are also kept in great variety for producing figures and patterns on velvet goods. The water surface is produced by passing the goods in a very damp state through the calender with hot or cold rollers, plain or indented, and sometimes with a slight lateral motion. The roller is heated by the insertion into it of a red hot cylinder. One of these

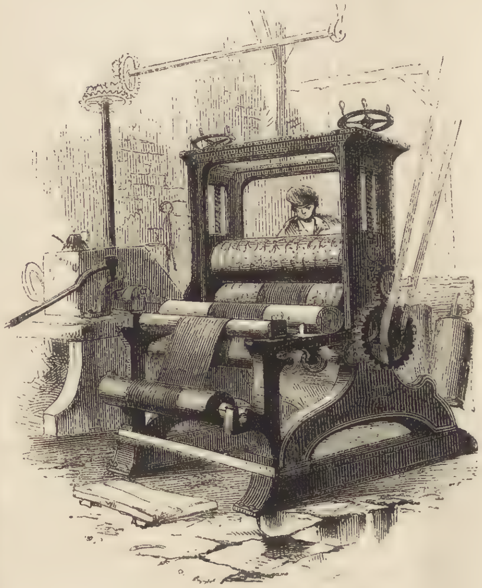


Fig. 402. EMBOSSING MACHINE.

embossing machines is shown in Fig. 402. From the great weight of calendering machines it is necessary that they should be fixed on the basement floor. After the cloth has received its final gloss at these machines, it is smoothly folded on a clean board, and taken to the making-up room to be measured preparatory to being rolled or folded for sale.

The calenderer usually undertakes many of the operations of packing, sheeting, and preparing goods for shipment. In order to suit the great extent and variety of manufacture in this country, and to adapt goods to the tastes or prejudices of an extensive range of customers, a multiplicity of foldings or lappings has been adopted. The objects proposed to be attained thereby appear to have been, 1. To preserve effectually the dressed surface of the goods from acute creases; 2. To imitate the external appearance of some descriptions of foreign goods; 3. To impart a peculiar external appearance to British goods,—an object which was further secured by stamping the words "British Manufacture" on the ends of the pieces, to show that they are home-made. In Irish cambrics and linens, a foreign fold has been adopted; the French flax, from superiority of climate and other causes, leading to the production of a superior fabric. Irish cambrics are therefore folded so as to imitate the French fold. The pieces, after being folded into lengths of about 12 inches, and twice laterally doubled, until the whole breadth of 34 inches is reduced to about $8\frac{1}{2}$ inches, are powerfully compressed, until fully flattened. They are then packed in purple-coloured wrappers or papers, and a small engraved card or ticket is attached to each piece, stating the length, which is generally 8 or $8\frac{1}{2}$ yards. As the importation of

manufactured cambrics was illegal, the cards, in real French cambrics, were attached by a silken string, so as to be easily cut away, to avoid seizure. The same method was adopted with the Irish goods; and such is the unreasoning preference of many persons for goods of foreign manufacture, that cotton cambrics, essentially of British manufacture, came to be folded, papered, and ticketed, in precisely the same manner.

In linens, hollands, and sheetings, and also in cotton shirtings and sheetings, the foreign fold is that of a cylindric roll, somewhat flattened by subsequent compression, for the purpose of safety to the goods, and diminution in space in carriage. The Irish and British linens, &c., are made up in the same manner.

Cotton prints, and the extensive varieties of cotton cloths of British manufacture, are also lapped in imitation of the rude Indian method practised in Hindostan long before the art of calico-printing was known to us. The method is, to double a piece of 20 yards, to reduce its length to 10 yards, which by again doubling is reduced to 5; and in this way they continue to redouble until the piece is reduced to a moderate length, capable of being packed in a chest or bale.

British muslins are usually folded to a yard in length, with a small allowance for extra measure: the folding is alternately from right to left, so that every part can be opened and examined with ease, like the leaves of a book, before it is cut open. The piece, when folded, is reduced by doubling it lengthwise to about 19 inches, and it is then folded across the breadth of about 13 inches. An ordinary sized trunk, 39×19 inches, thus contains three layers of pieces, and it is stated that, in the colonies, trunks of this kind are as much in demand as the muslins contained in them. "Even the Indian ornaments of gilt silver threads, which were at first woven into one end of each piece, although they did not exceed the value of twopence each, have been either greatly curtailed or totally given up, upon principles of economy. Even the cost of this trivial ornament has been computed to have amounted annually in Glasgow and Paisley to about 30,000*l*." [1]

Some kinds of handkerchiefs are folded in dozens; but for the African and a few other markets they are made up in pieces containing only eight handkerchiefs. Indeed, so successful have been the imitations of Indian and other foreign goods, in texture, in dye, in pattern, in finishing, and in the packages, that instances have occurred of seizure at the Custom-house, as India goods either illegally imported, or stolen from some of the Company's ships.

At Messrs. Goodier's calendering works at Manchester, the goods are measured, preparatory to being lapped or folded, either at a long table or at the hooking-frame. The measuring-table is a long smooth plank, with a scale of inches, feet, and yards marked at the side. A man stands at one end of the table, with the goods to be measured, and there is a boy at the other end. A length of cloth being spread out, the boy holds its extremity down at a line drawn on the table, while the man at his end marks a length of a certain number of yards, usually about five, with a piece of red or white chalk, according to the colour of the goods, the red being used for white stuffs. The boy then draws the cloth towards him, until the chalk-mark comes opposite to the line on the table, when he stops: the man then makes a second mark; the boy draws the length towards him until this mark arrives at the line, when the man repeats the mark, and so on until the proper length for a piece of goods is run off. Goods for the foreign market are measured by what is called *short stick;* those for the home market by *long stick.* In short stick, the yard is made to consist of "35 inches and a thumb," which is, in fact, 36 inches, the usual length of the yard, or it may be a trifle more. In long stick, the yard contains "36 inches and a thumb," which is equivalent to 37 inches. There is also *middle stick,* containing "$35\frac{1}{2}$ inches and a thumb" to the yard, and this is equal to $36\frac{1}{2}$ inches.

The measuring-table is used chiefly for goods that are made up into rolls: when made up in folds, the hooking-frame, Fig. 403, is used. This consists of

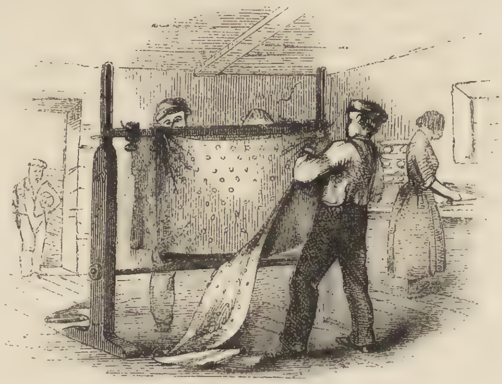


Fig. 403. HOOKING FRAME.

an iron bar, rather more than four feet long, graduated into inches and parts, supported by a wooden frame, and capable of being raised to different heights. At one extremity of the bar is a projecting needle, which is fixed: a second needle, attached to an iron slide, can be moved along the bar, and fixed at any point by means of a screw. The length of the yard varies at the hooking-frame as at the measuring-table. This length being determined for the goods to be measured, the children who act as hookers hang the cloth in regular folds upon the hooks, until a sufficient quantity is collected to form a piece, which is then cut off and removed, to be made up.

There are upwards of a hundred different methods of making up goods, and each method has its own particular name, such as the *falling lap,* the *Wigan way,* the *cloth way,* the *Preston way,* &c. Muslin, as already noticed, is made up in *book-folds,* in pieces of 24 yards; but usually two half-pieces, called *demis,* are made up in one book, with yellow paper under the first fold, to show the pattern, and the corners are secured with variegated silk thread. Tickets,

(1) Encyclopædia Britannica, Art. *Calender.*

containing various devices in gold or bronze, upon a blue or red ground, are pasted upon each piece, varying according to the market. Some of these tickets are of large size, and very costly; those printed in gold varying from 16*s.* to 25*s.* per 100, while the common forms of labels may be had for 2*s.* per 1,000. The devices on these tickets are as various as their appearance: they may contain the name, or the crest, or the coat of arms of some Portuguese or Greek merchant, or mottoes in various languages of Europe or of the East, naming the goods, or assigning some excellent qualities to them.[1]

A notice of calendering would not be complete without a description of the *common domestic mangle.* This, though very inferior to the machines described above, is yet a useful means of improving the surface of linen, and approaches in its results the more perfect operations of the calendering machine. It is simply an oblong wooden chest filled with stones, resting upon two cylinders which roll backwards and forwards over the linen, spread upon a polished table beneath. Formerly the chest was moved by means of a handle attached to an upper roller or windlass, to which straps from each end of the chest were attached. In this case the linen was wrapped round the cylinders, and the motion of the chest had frequently to be arrested and changed. This was laborious work, and it was a valuable improvement when a continuous motion of the handle in one direction would effect the object, and when a fly-wheel was added to equalise the motion. This was first done by Mr. Baker of Fore Street, London, whose plan was subsequently improved upon by Mr. Elisha Peechey, who received a silver medal from the Society of Arts on account of it in 1823. His mangle is represented in Fig. 404. F F is a frame of cast-iron with cross

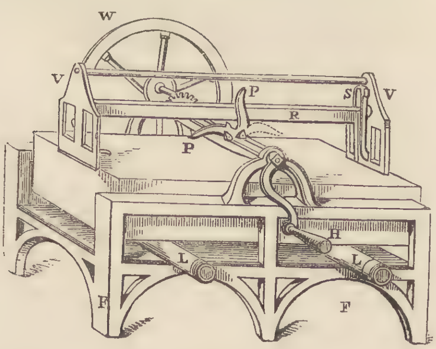


Fig. 404.

pieces and bridges to support the handle; P the cast-iron box, filled with large stones and gravel to give it weight; R, the rack, which is made to move up and down at each end in projecting grooves or slit pieces, as represented at S, and attached to vertical plates V V rising from the box. This rack is a stout metal bar, with a row of pegs along the middle of one side; and parallel with the line of these pegs projects a deep margin, intended to confine a pinion to its hold upon the pins while moving the rack backwards and forwards, by acting successively on each side of the series of pins. H is the handle, and W the fly-wheel fixed on the opposite end of the arch adjoining the centre of the fly-wheel, which, acting upon a circle of cogs, gives revolution to the pinion which carries the rack, and the upper part of which is seen in the figure; P P are two iron prongs, either of which, on being turned down, lifts up and sustains the mangle-box when the rollers L L are to be taken out. Fig. 405, will show the manner in which the rack

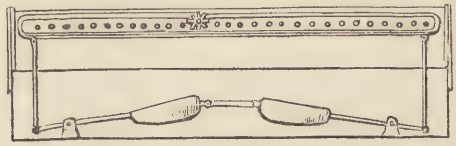


Fig. 405.

is balanced so as to produce the reciprocating motion. The rack being attached by each end to the connected levers, and counterpoised by the weights inside the mangle-box, the pinion traverses the row of pegs along the middle. When the pinion by the movement of the rack from right to left passes round the endmost peg, the rack will be lifted up, the weights in the box will sink, and the course of the pinion will be along the under side of the rack, until, on arriving at the last pin of the opposite end, the rack will again sink, the counterpoise rise to its present position, and the motion of the box be reversed with every alternation of the rack.

Various other patents have been taken out from time to time, several of which have been for vertical mangles, but although these occupy much less space than the common horizontal kind, yet they have never been in equal favour. Wilkinson's, otherwise known as Bullman's Cabinet Mangle, is one of the most efficient of the vertical kind.

CALICO. [See COTTON.]

CALICO-PRINTING. The art of producing a coloured pattern on cloth by the application of colouring substances appears to be of great antiquity. Homer notices the variegated linen cloths of Sidon as magnificent productions, and Herodotus says that the inhabitants of Caucasus adorned their garments with figures of animals, by means of an infusion of the leaves of a tree, and that the colours thus obtained were durable. Pliny's description of the art as practised by the ancient Egyptians, is almost identical with the modern processes. He says:—"They take white cloths, and apply to them not colours, but certain drugs which have the power of absorbing or drinking in colour; and in the cloth so operated on, there is not the smallest appearance of any dye or tincture. These cloths are then put into a cauldron of some colouring matter, scalding hot, and after having remained a time, are withdrawn all stained and painted in various colours. This is, indeed, a wonderful process, seeing that there is in

(1) In this article the Editor has availed himself of some of the information collected during a visit to Manchester, and published in a work by him, entitled, "The Useful Arts and Manufactures of Great Britain," 2 vols. 12mo. 1846 and 1850. Published under the direction of the Committee of General Literature and Education appointed by the Society for Promoting Christian Knowledge.

the said cauldron only one kind of colouring material; yet from it the cloth acquires this and that colour, and the boiling liquor itself also changes according to the quality and nature of the dye-absorbing drugs which were at first laid on the white cloth. And these stains or colours, moreover, are so firmly fixed as to be incapable of being removed by washing. If the scalding liquor were composed of various tinctures and colours, it would doubtless have compounded them all in one on the cloth; but here one liquor gives a variety of colours according to the drugs previously applied. The colours of the cloths thus prepared are always more firm and durable than if the cloths were not dipped into the boiling cauldron." In India the art of calico-printing has been practised for ages, and it derives its English name from *Calicut*, a town in the province of Malabar, where it was formerly carried on extensively. The large cotton chintz counterpanes, called *pallampoors*, which from an early period have been made in the East Indies, are prepared by placing on the cloth a pattern of wax, and dyeing the parts not so protected. Cortez noticed in Mexico that the inhabitants wore garments ornamented with coloured figures. The North American Indians have also been long acquainted with the art of applying different coloured patterns to cloth.

The art of calico-printing was practised in Asia Minor and the Levant several centuries before its introduction to Europe. It was not till the close of the seventeenth or the beginning of the eighteenth century that Augsburg became celebrated for its printed cottons and linens, and that city was long a school for the manufacturers of Alsace and Switzerland. The art was introduced into England, about the year 1676, by a Frenchman, who established works on the banks of the Thames, near Richmond. More extensive works were established soon after at Bromley Hall, in Essex. About the year 1700, the calico-printers were unexpectedly benefited by an act passed at the urgent solicitation of the silk and woollen weavers, to prohibit the importation of chintzes from India; whereupon several print-works were established in Surrey for the purpose of supplying imitations of these goods, which, as the silk and woollen weavers declared, had prevented their trades from thriving. The chintzes were produced by printing white Indian calicoes, the import of which was still allowed on payment of a duty. In 1712, a duty of 3*d.* per square yard was imposed on this printed calico, which two years after was doubled; but as the importation of white calico was scarcely checked by these harsh and unwise measures, the clamours of the silk and woollen weavers became louder, and the Government actually passed an act prohibiting the wearing of all printed calico, under a penalty of 5*l.* for each offence on the part of the wearer, and of 20*l.* on the seller.[1] In consequence of this law, the operations of the printer were confined to the printing of linen until the year 1730, when calico was again allowed to be printed, provided the warp was of linen, and the weft only of cotton; and even then it was subject to a duty of 6*d.* per square yard. With such impediments the process of the art was of course slow. In the middle of the last century only 50,000 pieces of the mixed cloth were printed each year in Great Britain, whereas, at the present time, a single manufactory will turn out six or eight times that quantity in the course of a year. About the year 1774, when Arkwright's machinery was producing calico with such wonderful facility, the legislature repealed the unjust law which prohibited the wearing of printed calico made entirely of cotton, imposing, however, upon it a duty of 3*d.* per square yard, which was raised in 1806 to $3\frac{1}{2}$*d.*

As printed calicoes and cottons formed an important article of dress with nearly all classes of the community, especially the lower, the continuance of this heavy duty was felt to be a great hardship, and interfered also with attempts to improve the art. Moreover, the actual revenue obtained from this source was but small, after deducting drawbacks on exports, and the expenses of collection. Thus in the year 1830, a revenue of 2,280,000*l.* was levied on 8,596,000 pieces, of which, however, about three-fourths were exported with a drawback of 1,579,000*l.*, and deducting the expenses of collection, the sum of 350,000*l.* only found its way into the exchequer. In the year 1831, the duty was wholly repealed, to the great advantage both of manufacturer and consumer; and since that time the art has been carried to a wonderful state of perfection, both chemically and mechanically. Printed goods which half a century ago were sold for 2*s.* 3*d.* per yard, may now be had for 8*d.* or less; and a cotton print, sufficient for a complete dress, may be had for 3*s.* or 4*s.*, or less. It is stated by Mr. M'Culloch, as an example of the prodigious increase of calico-printing, that in 1829, before the abolition of the duty, 89,862,433 yards of all descriptions of printed goods were exported; whereas in 1841, there were exported of printed cottons only 329,240,892 yards, of the declared value of 7,772,735*l.*

The object of calico-printing is to apply one or more colours to particular parts of cloth, so as to represent a distinct pattern, and the beauty of a print depends on the elegance of the pattern, and the brilliancy and contrast of the colours. The processes employed are applicable to linen, silk, worsted, and mixed fabrics, although they are usually referred to cotton cloth, or calico.

There are various methods of calico-printing, the simplest of which is block-printing by hand, in which the pattern or a portion thereof is engraved in relief upon the face of a block of sycamore, holly, or pear-tree wood, backed with deal, and furnished with a strong handle of box-wood.

Fig. 406.

The block, Fig. 406, varies in size from 9 to 12 inches long, and from 4 to 7 inches broad. In

(1) An act was also passed in the same year, (7th George I.) prohibiting the wearing of buttons or button-holes made of cloth, the object being to encourage the use of silk.

some cases the pattern is formed by the insertion into the block of narrow strips of flattened copper, the interstices being filled with felt. This gives a very distinct impression. The block is charged with colour by pressing it upon a surface of woollen cloth stretched tightly over a wooden drum. This, which is called the *sieve*, is made to float in a tub of size or thick varnish, for the purpose of giving it elasticity. The sieve is covered with the colouring matter by a child called the *tearer*, (probably from the French *tireur*,) who takes up with a brush a small quantity of the colour from a pot, and spreads it uniformly over the surface of the sieve, and every time that the man presses his block upon the sieve in order to charge it with colour, it is the duty of the tearer to brush over the woollen surface in order to erase the mark of the block, for if this were not done, the block would not be equally charged with colour.

The calico having been prepared for printing by *singeing*, *bleaching*, and *calendering*, [see BLEACHING and CALENDERING,] a number of pieces are stitched end to end, and lapped round a roller, or arranged in folds in the printing shop, which is a well lighted apartment, the air of which is kept warm in order to dry the colours soon after they are applied, for which purpose the cloth is passed over hanging rollers, so as to expose a large surface. The printing table is about 6 feet long, and is made of mahogany, marble,

Fig. 407. BLOCK PRINTING.

or flagstone, or any material capable of forming a flat hard surface. This table is covered with a blanket, upon which the calico is spread, and the block being charged with colour as above described, the man applies it to the cloth in the exact spot required, and in some cases strikes it on the back with a wooden mallet, in order to transfer the impression fully. Thus by repeated applications of the block, a pattern is produced in one colour. Care is required to place the block in the exact spot, so as to make one impression exactly join or fit in with the previous impression, and for this purpose the block is furnished with small pins at the corners, which make holes in the cloth, and serve as a guide to the printer. If the pattern contain three or more colours there must be as many blocks, all of equal size, the raised portions in one, which take up colour, corresponding with depressed portions in the others which do not take up colour. In order therefore to print a piece of cloth 28 yards long, and 30 inches broad, with three blocks, each measuring 9 inches by 5, there must be 672 applications of each.[1] But if the design consist of parallel stripes of different colours, they may be applied with one block at a single application on the same part of the cloth, by arranging the colours in small tin troughs, and transferring a portion from them to the sieve by means of a small wire brush, and the colour is then distributed evenly in stripes over the surface by a roller covered with woollen cloth. In those patterns in which the colours are blended into one another at the edges, in what is called the *rainbow style*, they are first blended by a brush on the sieve before being taken up by the block. Stereotyping has been applied to the production of printing blocks. A small mould is produced from a model of the pattern, and copies are then made by pouring fusible metal into it. [See BISMUTH.] A number of these plates are joined together, and mounted in a stout piece of wood, and thus form a printing-block.

A machine called the *Perrotine*, in honour of its inventor M. Perrot of Rouen, is in use in France and Belgium as a substitute for hand-block printing. It is thus described by Dr. Ure:—"Three wooden blocks, from $2\frac{1}{2}$ to 3 feet long, according to the breadth of the cloth, and from 2 to 5 inches broad, faced with pear-tree wood, engraved in relief, are mounted in a powerful cast-iron frame-work, with their planes at right angles to each other, so that each of them may, in succession, be brought to bear upon the face, top, and back, of a square prism of iron covered with cloth, and fitted to revolve upon an axis between the said blocks. The calico passes between the prism and the engraved blocks, and receives successive impressions from them as it is successively drawn through by a winding cylinder. The blocks are pressed against the calico through the agency of springs, which imitate the elastic pressure of the workman's hand. Each block receives a coat of coloured paste from a woollen surface, smeared after every contact with a mechanical brush. One man with one or two children for superintending the colour-giving surfaces, can turn off about 30 pieces English per day, in three colours, which is the work of fully 20 men and 20 children in block printing by hand."[2]

Copper-plate printing similar to that used in the production of engravings has also been applied to calico-printing, but the perfection to which cylinder-printing, next to be described, has been brought, rendered the extension of this method unnecessary.

The invention of *cylinder* or *roller-printing*, is the

(1) Fig. 407 shows the general arrangements of the printing-room in printing by hand. At the time our artist made this sketch, the printers were working in the *discharge style* (which will be noticed further on): the acid used to discharge the colour is supplied to the sieve by means of an inverted bottle, as shown in the cut, so that the services of the tearer are not required.

(2) Dictionary of Arts, Manufactures and Mines, Article "Calico-Printing."

greatest achievement that has been made in the art, producing results which are truly extraordinary: a length of calico equal to one mile can by this method be printed off with four different colours in one hour, and more accurately and with better effect than block printing by hand. One cylinder machine, attended by one man, can perform as much work in the same time as 100 men attended by 100 tearers. The effect of this beautiful machine has been greatly to cheapen cotton prints, and to create an enormous demand for them, both for the home and the export trade, so that while apparently superseding labour in one direction it creates a demand for it in all directions.

The invention of this machine is attributed to two persons who had no connexion with each other: the one is a Scotchman named Bell, who about the year 1785 practised at Monsey near Preston; the other was named Oberkampf, a calico printer at Jouy in France. We will endeavour, with the assistance of a diagram, to explain the principle of the machine as arranged for printing a pattern in three colours. The cylinders upon which the pattern is engraved, one cylinder for each colour, are shown in section at *c*, Fig. 408, and a view of one of them in Fig. 409. Each cylinder is mounted on a strong frame-work, so as to revolve against two other cylinders D and *e*: the cylinder *e* is covered with woollen cloth, and dips into a trough *i*, containing the colouring matter properly thickened, so that as *e* revolves it takes up a coating of colour and distributes it over the engraved roller *c*. D is a large iron drum covered with several folds of woollen cloth, so as to form a somewhat elastic printing surface: an endless web of blanketing *a a* is made to travel round this drum, which serves as a sort of guide, and defence, and printing surface to the calico *b b* which is being printed. Now it is obvious from this arrangement, that the cylinder *e* in revolving must spread the colour uniformly over the engraved cylinder *c*, whereas it is wanted only in the depressed or engraved parts; the excess of colour has therefore to be removed before the roller comes in contact with the calico, or instead of being ornamented with a pattern it would be disfigured with an unmeaning patch of colour. The superfluous colour is removed by a sharp edged knife or plate *d*, usually of steel, called the *doctor*.[1] This is so arranged that the colour scraped off shall fall back into the trough *i*. Each engraved cylinder is usually provided with two doctors, one called the *colour doctor*, *d*, and the other the *lint doctor*, *d'*. The object of the latter is to remove the fibres which the roller acquires from the calico. Doctors are made of gun-metal, bronze, brass and iron alloys, as well as of steel, that metal being used which is least acted on by the colouring materials and mordants used in the troughs.

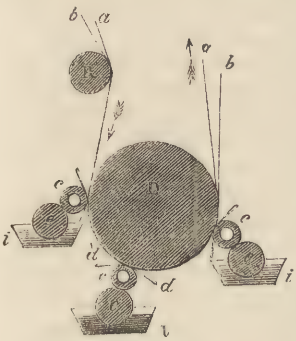


Fig. 408.

Fig. 409.

Fig. 410. CYLINDER PRINTING MACHINE.

Fig. 410 is a view of a cylinder macnine for printing colours. It has been engraved from a sketch made by Mr. Prior, in the well arranged print-works of Mr. Joseph Lees of Manchester, who

(1) The origin of this term has been explained by Mr. Baines in his History of the Cotton Manufacture:—When Mr. Hargreaves, a partner in the factory at Monsey near Preston, where cylinder printing was first introduced, as already noticed, was making some experiments with the process, one of his workmen said, "All this is very well, Sir; but how will you remove the superfluous colour from the surface of the cylinder?" Mr. Hargreaves took up a common knife, and pressing the edge parallel with the axis of the revolving cylinder, at once showed its action in removing the colour. After a short pause the operative exclaimed, "Oh sir, you have *doctored* it!" a common phrase for "You have *cured* it;" and the contrivance has ever since retained the name of *the doctor*. Another account is, that the word *doctor* is a corruption of the Latin, *abductor*.

kindly allowed the Editor and the Artist to examine all the processes in detail. Some of the machines are very complicated in appearance, as many as eight colours being printed at once by one machine; but this complication is only apparent, for it is produced by the repetition of similar arrangements eight times over, each engraved roller, provided with its own colour trough, &c., revolving against the iron drum D; but very great nicety of arrangement is required to bring all these rollers to bear upon the cloth, so as to print at the exact spots required for forming a complicated pattern; but when the proper adjustment is made, a machine for printing eight colours acts with as much precision and regularity as a machine arranged for a fewer number of colours.

As fast as the calico is printed, it is drawn through a long gallery or passage, raised to the temperature of nearly 200°, by means of a furnace flue which traverses its whole length. The upper surface of the gallery is covered with rough plates of cast-iron which radiate heat upon the printed goods. A piece of calico of 28 yards is drawn through the gallery in about two minutes, during which the colours become dried and set.

The printing cylinders vary in length from 30 to 40 inches, according to the width of the calico: the diameter varies from 4 to 12 inches. Each cylinder, A, and in section C, Fig. 411, is bored through the axis

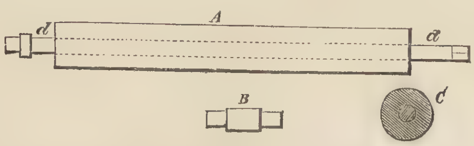


Fig. 411.

d d, and accurately turned from a solid piece of metal. For some styles of pattern the engraving is done by hand, but as this is expensive, it is usual to adopt Perkins's method of transferring engravings from one surface to another by means of small steel rollers, B. The pattern is first drawn upon a scale of about 3 inches square, so that this size of figure being repeated a number of times will cover the printing cylinder. The pattern is then engraved upon a roller of soft steel about 1 inch in diameter, and 3 inches long, so as to occupy its surface exactly. This small roller, which is called the *die*, is next hardened by heating it to redness and suddenly quenching it in cold water. The roller thus hardened is then put into a rotatory press, and made to transfer its design to a similar small roller in a soft state, called the *mill*. The design which was sunk in the die, now appears in relief on the mill. The mill in its turn is hardened, and being put into a rotatory press, engraves or indents upon the large copper cylinder the whole of the intended pattern. This is of course a work of time, and requires considerable care to make the numerous junctions of the small roller exactly fit each other upon the printing cylinder. By this process, however, a pattern may be imparted to a large cylinder at the cost of about 7*l*., while if engraved by hand it might cost seven or eight times that sum. By the method just described, a worn cylinder can be renewed and made equal to a new one.—The pattern is also sometimes produced by *etching*, in which case the cylinder is covered with a thin coat of varnish, and on this the pattern is traced with a diamond or steel point. Aqua-fortis is then applied to the surface, which bites into or corrodes the parts which have been removed by the point. This point or tracer is sometimes applied in a manner similar to that of the eccentric chuck of a lathe, by which means the surface is covered with patterns, or a ground-work for patterns of great variety and beauty. Eccentrically engraved cylinders are exported from Manchester, and the foreign printer adds the pattern. The cost of a copper cylinder before engraving, varies from 5*l*. to 7*l*., and the cost of engraving from 5*l*. to 10*l*.—The electrotype has also been used for producing the design on the printing cylinder.—The design is also sometimes cut in relief upon wooden rollers; or formed by the insertion of flat pieces of copper edgeways. This is termed *surface printing*, probably from the circumstance of the thickened colour being applied to a tense surface of woollen cloth, against which the cylinder revolves and takes up colour. A combination of wooden and copper rollers forms what is called the *union printing-machine*.

Another method of calico-printing remains to be described, namely, *press-printing*, by which several colours can be printed at once. The cloth to be printed is wound upon a roller at one end of the machine, and the design, which is formed in a block of mixed metal about 2½ feet square, is supported with its face downwards in an iron frame, and can be raised or lowered at pleasure. The face of the block is divided into as many stripes, ranging crossways with the table, as there are colours to be printed. If, for example, the pattern be made up of five stripes of different colours, and each stripe be 6 inches broad, and as long as the breadth of the cloth, the colours have to be applied without mingling or interfering with each other. This is accomplished in the following manner:—The side edges of the table are furnished with a couple of rails similar to a railway, and upon this is a shallow tray or frame, capable of moving backwards and forwards upon wheels. Within this frame is a cushion of about the same size as the printing-block, and by its side are five small troughs containing the thickened colours. By means of a long piece of wood, formed so as to dip into all the troughs at once, the tearer applies a small portion of each colour to the surface of the cushion, and spreads them evenly into five portions or stripes, taking care not to mix them; but making their breadth equal to that of the stereotype rows on the block. The cushion being prepared, the frame is rolled along the railway until it is immediately under the printing-block, which the pressman then lowers upon the cushion, by which means the five stripes of the block become charged, each with its proper colour. The block is then raised, the frame rolled away, and the block brought down upon the cloth,

which it prints with five rows of different colours. On raising the block, the cloth is drawn forward about six inches in the direction of its length, or exactly the width of one stripe on the block; the tearer again pushes forward the cushion with the colours renewed, and the block is again charged and applied to the cloth. Now, as a length of the cloth equal to the width of a stripe is drawn from under the block at each impression, every part of the cloth is brought into contact with all the stripes on the block. Great care is required so to adjust all the moving parts of the press, that the colours may not mingle, and distort the pattern.

Having thus briefly described the chief mechanical processes of calico-printing, we come now to notice the chemical. The colours used in calico-printing are derived from all the three kingdoms of nature, but it seldom happens that solutions, infusions, or decoctions of these colours admit of being applied at once to the cloth without some previous preparation, either of the cloth itself, or of the colouring material. It is often necessary to apply some substance to the cloth which shall act as a bond of union between it and the colouring matter. This substance is usually a metallic salt, which has an affinity for the tissue of the cloth as well as for the colouring matter when in a state of solution, and forms with the latter an insoluble compound. Such a substance is called a *mordant*, (from the Latin *mordere*, to bite,) a term given by the French dyers under the idea that it exerted a corrosive action on the fibre, expanding the pores, and allowing the colour to be absorbed. The usual mordants are common alum and several salts of alumina, peroxide of iron, peroxide of tin, protoxide of tin, and oxide of chrome. These have an affinity for colouring matters, but many of their salts have also a considerable attraction for the tissue of the cloth, which withdraws them to a certain extent from their solutions. Mordants are useful for all those vegetable and animal colouring matters which are soluble in water, but have not a strong affinity for tissues. The action of the mordant is to withdraw them from solution, and to form with them, upon the cloth itself, certain compounds which are insoluble in water.

In calico-printing it is generally necessary to bring the mordant or the colouring matter into such a state of consistency as to prevent it from spreading beyond the proper limits of the design. This is done by the use of *thickener*, the most useful of which is wheat-starch, and flour; but many others are used, such as gum-arabic, British gum, high-dried potato starch, gum-Senegal, gum-tragacanth, jalap, pipe-clay, or China-clay mixed with gum, dextrine, potato and rice starch, sulphate of lead mixed with gum, and many others. The choice of proper thickeners requires attention; for two similar solutions of the same mordant equally thickened, but with different thickeners, may give different shades of colour when used with the same colouring material.

The colours, with the proper thickeners, &c. are prepared in vessels furnished with steam-jackets, as shown in Fig. 412, for raising the contents to the required temperature.

Fig. 412. PREPARATION OF COLOURS, &c.

Although the different methods of printing are numerous, and the combinations of colours and shades of colour almost infinite, yet each colour in a pattern must, in the present state of the art, be applied by one of six different *styles* of work. These are termed, 1, the Madder style; 2, Printing by steam; 3, the Padding style; 4, the Resist style; 5, the Discharge style; and 6, the China-Blue style. By the proper combination of two or more of these styles any pattern however complicated is produced.

The madder style is so called from its being chiefly practised with madder; but it is applicable to most soluble vegetable and animal colouring matters. The first process in this style is to print the calico with a mordant; that is, instead of printing at once with colour, the parts of the surface which are to have a madder colour imparted to them, are first impressed with a mordant. After the calico has passed through the hot flue, it is in many cases suspended free from folds for one or two days in what is called the *ageing-room*, where by exposure to air the mordant, or a portion thereof, undergoes a chemical alteration, whereby it becomes attached to the cloth in an insoluble state. Any portion of the mordant that remains in a soluble state must be completely removed, or the colour in being subsequently applied would spread over the surface, instead of being confined within the limits of the pattern. The superfluous mordant is removed by passing the dried calico through a warm mixture of cow-dung and water. This is called *dunging*. The mixture is usually contained in two stone cisterns, placed end to end, each about 6 feet long, 3 feet wide, and 4 feet deep. The mixture in one cistern is formed with about 2 gallons of dung to the cistern full of water, heated to about 160° or 180°. The second cistern contains about half this quantity of dung. The calico, guided by rollers to keep it free from folds, is drawn quickly through the first trough, and then immediately through the second. It is then washed in clean water in what is called a wince-pit, and again in a dash-wheel. [See BLEACHING.] Dunging is further useful in removing the thickening paste by which the mordant is applied, and it also determines

a more intimate union between the mordant and the fibre of the cloth. The process is necessary for alum, iron, and tin mordants, when applied to the cloth before the colouring matter.

The difficulty of procuring cow-dung in sufficient quantities has led to attempts to find substitutes in those chemical substances which an analysis of dung indicate as the essential ingredients. Thus a solution of phosphate of soda and phosphate of lime, with a little glue or some other form of gelatine, has been used under the name of *dung-substitute*, or simply *substitute.*

After washing in cold water, the mordanted cloth is winced in a weak solution of substitute and sise. It is then ready for the colour. This is not applying by the process of printing, but simply by drawing the cloth for two or three hours through a solution of the colouring material. [See Dyeing.] The colour attaches itself permanently to those portions of the cloth to which the mordant has been applied, and forms a true chemical compound therewith; but on the unmordanted portions the colour is feebly attached, and is subsequently removed by washing in soap and water, or in bran and water, or in a dilute solution of chloride of lime. This last washing is called *clearing.*

Such is a very meagre outline of the most important processes concerned in printing and dyeing a piece of calico according to the madder style. The processes actually required for finishing a piece of cloth are numerous, as for example, in producing a red stripe upon a white ground, the bleached cloth is submitted to nineteen operations, as follows:—1. Printing on mordant of red liquor, (a preparation of alumina,) thickened with flour, and dyeing; 2. Ageing for three days; 3. Dunging; 4. Wincing in cold water; 5. Washing at the dash-wheel; 6. Wincing in dung-substitute and sise; 7. Wincing in cold water; 8. Dyeing in madder; 9. Wincing in cold water; 10. Washing at the dash-wheel; 11. Wincing in soap-water containing a salt of tin; 12. Washing at the dash-wheel; 13. Wincing in soap-water; 14. Wincing in a solution of bleaching-powder; 15. Washing at the dash-wheel; 16. Drying by the water extractor; [See Dyeing.] 17. Folding; 18. Starching; 19. Drying by steam.

The operations of washing and drying are very important, and provision is made for them on a very complete scale. Fig. 413 is a view of the washing and drying apparatus at Mr. Lees's works. The pieces of cloth are brought down into water-tanks, passing under and over rollers, furnished with balance-weights to keep the calico stretched: these weights can be adjusted on their levers, so as to vary the tension to any degree required. In some cases the bottom of the tank is supplied with water in jets, so that the calico is subjected to the dashing action of the water. In passing out of the washing machine, the calico is received on a skeleton roller, where it is smoothed by an attendant, and passes from this to the drying cylinders, Fig. 413, (see also Fig. 399,) and in section in Fig. 414, where the arrow on the left shows the calico proceeding from the washing-machine, passing over a guide-roller R, and then over

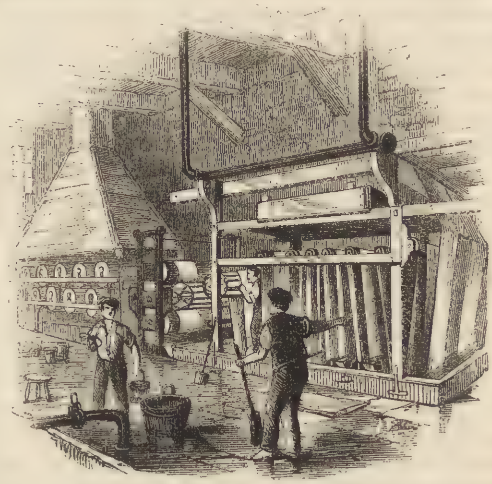


Fig. 413. WASHING AND DRYING.

the drying cylinders, which are of metal, and heated by steam. It is then guided by a second roller R to the drum D, on which it is finally wound.

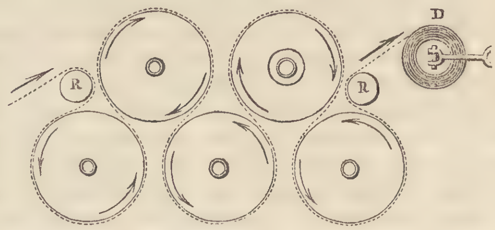
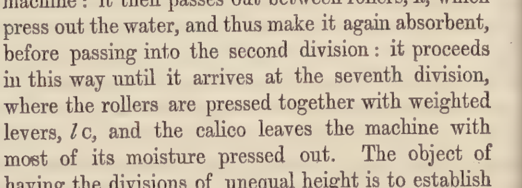


Fig. 414.

Another form of washing-machine is shown in section, Fig. 415. The cloth is arranged in folds upon a shelf to the left of the figure, whence it is

Fig. 415.



guided by rollers into the first vat or division of the machine: it then passes out between rollers, R, which press out the water, and thus make it again absorbent, before passing into the second division: it proceeds in this way until it arrives at the seventh division, where the rollers are pressed together with weighted levers, *l* C, and the calico leaves the machine with most of its moisture pressed out. The object of having the divisions of unequal height is to establish a current of water; for the tallest vat being first supplied, overflows into the next, and this into the third from the right, until the collected overflowings escape by the lowest vat. In this way a current is kept up, and the calico, moving in a contrary direction to that of the current, is completely washed.

The second style of calico-printing is by steam. The colours which attach themselves firmly to the

cloth by being printed on it with a mordant are not numerous, but by exposing the goods so printed to the action of steam, an intimate combination takes place between the tissue, the colouring matter, and the mordant. The mechanical arrangements for steaming are various. In some works the cloth is suspended free from folds in a small chamber of masonry, into which steam is admitted. In other works the goods are placed in a large deal box, the lid of which is made nearly steam-tight by edges of felt, and the steam is admitted through a pipe perforated with a multitude of small holes, which traverses the box. But the common method, Fig. 416,

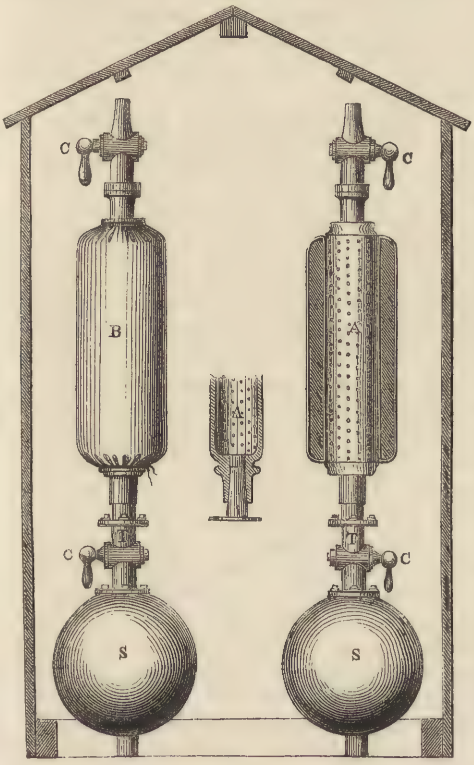


Fig. 416. STEAMING APPARATUS.

is to coil the calico round a hollow copper cylinder, A, perforated with holes, the lower end of which is connected with a steam-pipe. The cylinder is prepared by mounting it in a horizontal position in a frame. A roll of blanket is first lapped round it, then a piece of white calico, and lastly, three or four pieces of the printed and dried calico stitched end to end. The cylinder is then fixed upright in a small apartment furnished with a chimney to carry off the steam. The open end of the cylinder is screwed to a pipe connected with the spheres S S, which are supplied with steam from the main boiler of the works, the quantity being regulated by a stop-cock C. The temperature is kept at 211° or 212° to prevent much condensation, which makes the colours run. A higher temperature is injurious, but a slight condensation is required to keep the goods moist. The steaming is carried on for from 20 to 40 minutes, according to the nature of the colour. When the steam is cut off, the cloth is unrolled immediately, to prevent condensation. On exposure to the air, the thickening material soon solidifies, and the goods become dry and stiff. The cloth is then aged for a day or two, and the thickener gently washed out with cold water.

The operation of steaming not only attaches the colour firmly, but gives it brilliancy and delicacy of finish. It is not always adopted, for some colours become firmly attached to the cloth by mere exposure to air. A variety of cheap goods for some of the foreign markets are printed in *fugitive* colours; these not being fixed by steaming or by a mordant are called *spirit, fancy,* or *wash-off* colours.

The third style, called the *padding style,* applies to mineral colours only. By this style a pattern may be produced on white or coloured ground, and a ground may also be formed for the design in other colours. For the latter purpose the *padding machine* is used. This is almost identical with the starching mangle described in CALENDERING, the trough containing the thickened colouring matter instead of starch. A roller covered with blanket dips partly into the trough, and above and in contact with this is another roller, and the cloth to be padded passes between the two. When the cloth is uniformly imbued with the colour, it is dried at a temperature of 212°. If the colour is to be applied to the face of the cloth only, the common printing machine with a roughened roller is used instead of the padding machine. The ground is sometimes produced by the union of two colours in solution forming within the fibre of the cloth itself an insoluble coloured precipitate. For this purpose the cloth is first passed through one coloured solution, and then dried. It is next passed through the other coloured solution; the two then react upon each other, and produce the desired effect. Or the cloth may be padded in one solution, and afterwards winced in the other. In order to produce a design on a white or coloured ground, the cloth is printed with one of the solutions, and then padded or winced in the other.

In the next style of printing, the *resist style,* the white cloth is printed with a *resist paste,* the object of which is to prevent those portions of the cloth to which it is applied in the form of a pattern, from taking up colour when the cloth is passed through the dye-beck. A white design on a coloured ground is a simple example of this style. There are two classes of resists, one to prevent a mordant from attaching itself to the portions of the cloth so protected, and the other to shield the cloth from colouring matter. Some resists act mechanically; such are *fat* resists. Others act chemically as well as mechanically.

The object of the fifth or *discharge style* is to produce a white or coloured figure upon a coloured ground. For this purpose the dyed or mordanted cloth is printed with a substance called the *discharger,* which acts either on the colouring matter or on the mordant before the cloth is exposed to the dye. The discharger acts by converting the colouring matter on

the mordant into colourless or soluble products, which may thus be removed so as to allow the parts thus discharged to be dyed in another colour. A vegetable or animal colouring matter is usually discharged by chlorine and chromic acid; and a mordant is dissolved by an acid solution.

By this style are produced the well-known imitations of Bandana handkerchiefs, in which white figures are formed on a ground of Turkey-red by means of an aqueous solution of chlorine. This is made to flow down through the red cloth in certain points, which are defined and circumscribed by the pressure of hollow lead types inserted into plates of lead contained in a hydraulic press. The press is furnished with a pair of pattern plates, one attached to the upper block of the press, and the other to the movable part or sill. From twelve to fourteen pieces of cloth previously dyed in Turkey-red are stretched over each other as evenly as possible, and then rolled round a drum. A portion of the fourteen layers equal to the area of the plates being drawn through between them, the press is worked, and the plates are brought together with a force of upwards of 300 tons. The solution of chlorine is then allowed to flow into the hollows of the upper lead plate, whence it descends on the cloth, and percolates through it, extracting the Turkey-red dye, the intense pressure preventing the bleaching liquor from spreading beyond the limits of the figures perforated in the plates. When a certain quantity of bleaching liquor has passed through, water is admitted in a similar manner to wash away the chlorine. The pressure is then removed, and another square of the fourteen layers is moved forward under the plates, and the process is repeated. When all the pieces have been discharged, they are winced in water, and further treated so as to improve the lustre both of the white and of the red.

The sixth and last style of printing is for *china-blue*, a peculiar style, practised with indigo only, two or three shades of colour being commonly associated with

Fig. 417. INDIGO VATS

white. The bleached calico is printed of the required pattern with a mixture of indigo, orpiment, sulphate of iron, gum, and water. It is then aged for a day or two, and afterwards stretched in perpendicular folds on a rectangular frame of wood, Fig. 417. This is immersed in a certain order in three liquids, contained in stone cisterns, the tops of which are on a level with the ground: 1. in milk of lime; 2. in a solution of sulphate of iron; 3. in a solution of caustic soda. The frames are dipped several times alternately into the first and second cisterns, with exposure to the air for a short time between each dip: they are not dipped so frequently into the third cistern, but the dipping into this follows immediately after that in No. 2. By these operations, the insoluble indigo which had been applied to the surface becomes converted into soluble indigo, or *indigotin*, [see Dyeing,] which is dissolved and transferred to the interior of the fibres, where it is precipitated in the original insoluble form.

Such is a general outline of the mechanical and chemical arrangements of a large print-work. In addition to these, every calico-printer must have the means of producing a constant succession of new patterns; for, were he to neglect to satisfy the craving after novelty in dress which seems to form a part of the mental constitution of all classes, his goods would be neglected, however fine in material, excellent in weaving, elegant in design, and tasteful in the choice, variety, and combination of colour. The spring or the winter fashions of each year must be *new;* and although millions of patterns have preceded those of any particular year, yet the patterns of each year must be stamped with the characteristic of novelty, or they will not sell. The production of this novelty requires months of previous preparation; and it is the business of a peculiar set of artists or pattern designers to furnish the printer with a large variety of designs, from which he selects those which he thinks likely to suit the taste of his customers. In some cases, the new patterns are sent out first to the distant foreign markets, such as those of South America: in other cases, patterns which have become old in this country are sent to the colonies, or to distant parts, as new; just as the fashionable novel, which has accomplished its short cycle of one season, is sent abroad, to initiate our colonists into the mysteries of high life at home.

A set of designers is usually attached to large print-works, consisting of two or three artists, and four or five apprentices. The designs furnished by them often amount to several thousands every year, from which the printer selects those which appear likely to succeed, either from novelty of design or the tasteful distribution of form and colour. Some designers work on their own account, and sell their designs at prices varying from a few shillings to many pounds. A skilful designer may meet with permanent employment at five or six guineas per week; but the average varies from 35*s.* to 50*s.* per week. Some printers have agents in the towns of France, and elsewhere, where print-works are carried on, and it is their duty to forward to their employers specimens of all the new patterns, as fast as they appear. The French are as superior to us in the art of design as we

are to them in the mechanical departments of calico-printing. It is, however, to be hoped that the Schools of Design which have been established in the manufacturing towns of this country will do much to cultivate and improve the native taste. Whatever patronage is bestowed on these excellent institutions will, if properly applied and rightly directed, be a national benefit.

An Act passed in the 34th George III. gave to the inventor or printer of any new and original pattern for printing linen, calico, cotton, or muslin, the sole right and property in the same for three months from the time of publication. This was felt to be an insufficient protection; for no printer would employ an eminent artist to produce designs which in so short a time would become public property. Accordingly, a parliamentary inquiry was instituted, with a view to extend the copyright of designs, and in 1840 a select committee of the House of Commons published their report, which was favourable to such extension. In September, 1842, a new Act came into operation, by which a copyright of nine months was secured to designs for "garment-printing," and of three years to designs for "furniture-printing;" every design to be registered in a book kept by a registrar appointed by the Board of Trade. The greater protection granted to furniture-printing was on account of their being more costly than garment-prints; the mere drawing and engraving of some furniture-patterns costing from 50*l.* to 100*l.* A still greater expense is incurred in "making out the pattern:" that is, reducing it to such a scale, and making such a distribution of its parts, as will cause the several portions to "justify," or fit in with each other, when engraved on separate blocks or cylinders. Some patterns require to be drawn five or six times, because a very small imperfection in furniture-designs is at once detected. The patterns are designed on white card, each about 12 or 14 inches by 8 or 10, or less than this; the object being to give so much of the pattern as will represent it fairly. When a pattern has been approved, it is examined, to ascertain that every *repeat* is equidistant, that it is repeated at proper distances, and that there are not four sketches and a half, or five and a half, or five and a quarter, in what would be the circumference of the roller: a sketch is prepared which is made to agree exactly with the roller.

The reader who is interested in this subject will find a variety of curious and useful information in the minutes of the evidence taken before the Parliamentary Committee. The limits of this article will allow us to give only a few brief particulars. Mr. Salis Schwabe, a Manchester calico-printer, stated that the designing portion of his establishment cost about 800*l.* per annum. In 1838, between two and three thousand designs were produced, of which 500 were selected for engraving. The whole cost for designing and engraving these patterns was from 5,000*l.* to 5,500*l.*, or an average of 11*l.* per pattern; about 700 rollers being required to make out the 500 patterns. Of these patterns, 100 were decidedly successful, and 50 had a middling result. The cost of the unsuccessful patterns must of course be borne by the successful ones; thus bringing the cost of each successful pattern to about 35*l.* Two or three months are usually occupied in designing and engraving patterns, previous to their being ready for taking orders. Designs for light goods are got ready for the engraver in June, July, and August. In this last month the engravers have completed a portion of their work, and in September the first exhibition of patterns takes place, preparatory to sales for the distant markets, such as those of South America; but many of these patterns are suitable for the home market afterwards. Orders are taken for the home market in January, and the goods are delivered in February and March; so that the same designs may be published for one market in October, and for the home market in March. The sale continues throughout the summer.

When the printer has his own idea of a new pattern, he describes to the designer in words the style, the stripe, check, diagonal set, natural flowers, or other objects. He does not exhibit another pattern, for, as Mr. Schuster remarked, "I have found by experience that indolence is an inherent quality even of draftsmen, and that they will come very near if I give them a pattern, and consequently I have desisted from that plan," for a pattern "assists the draftsman in remaining idle, in not exerting his own ingenuity in composing, in producing *novelty*," which is the thing most wanted.

One of the most novel and original patterns ever produced was by accident. Messrs. Simpson & Co. having to print a quantity of cloth in parallel stripes, as one piece was going up on the blanket the next piece came in another shape on the other side and cut a little across the pattern, so that the stripes being thrown angularly on each other, produced a new effect, which received the name of the *Diorama* pattern. This became so great a favourite that the printers are said to have sold 25,000 pieces of it in one day.

It appears from the evidence of several of the witnesses before the Committee, that the art of design has retrograded in England. When the printing trade was confined to the vicinity of London, pattern-drawing flourished. Mr. Thomson of Clitheroe says:—"The designs of several distinguished artists are still remembered with admiration; and Raymond, Kilburn, Wagner, and Edwards, are regarded as the old masters of the English school of design in calico-printing. I have the good fortune to possess a volume of drawings of this period, in which pattern-drawing is elevated to the dignity of a fine art. The art of printing since that period has made gigantic strides, and is now one of the most beautiful and refined of the chemical arts. The art of designing has at the same time retrograded." Other witnesses stated that the best printers did not hesitate to copy French patterns almost exactly.

There are many excellent treatises on Calico-Printing. The most elaborate is that by M. Persoz, Professeur à la Faculté des Sciences de Strasbourg,

entitled, "Traité théorique et pratique de l'Impression des Tissus," 4 vols. 8vo. Paris. 1846, with a quarto atlas of plates. The work itself contains 165 wood engravings and 429 actual specimens of printed calico in its various stages and styles, neatly pasted in among the type, producing a very pleasing effect. These specimens were furnished to the author by some of the principal calico-printers of Alsace, Switzerland, Normandy, the environs of Paris, England, and Scotland. Each house sent a sufficient quantity of print for the whole impression of the work, accompanied by a written description of the process adopted for producing each specimen. This highly useful method of illustration was first adopted in 1835, by Dr. Thomas Thomson, who published in the "Records of General Science," a valuable series of papers on this Art. It has also been adopted by Mr. Parnell in his Treatise on Calico-Printing, contained in his excellent work on "Chemistry applied to Manufactures," 8vo. London. 1843.

CALOMEL, the protochloride of mercury. [See MERCURY.]

CALORIMETER. [See HEAT—THERMOMETER.]

CAMBOGE or GAMBOGE, a gum resin, forming a well-known yellow water-colour. The best gamboge is from Siam and the kingdom of Camboja, (whence its name,) and is said to be the produce of *Garcinia Cochinchinensis*, the broken leaves and branchlets of which form a yellow milky juice, which is run into bamboos, so as to form cylindrical sticks. Another kind, which is suffered to harden in masses, which are covered with leaves, is said to be derived from *Cambogia gutta*. Dr. Wight, however, states that the tears of cambogia gutta are a substance altogether distinct from true gamboge. The best gamboge is brittle and inodorous, of conchoidal fracture, orange-coloured, or reddish yellow, smooth, and somewhat glistening. Its powder is bright yellow. It may be resolved into resin and gum by the successive action of ether and water. The finest gamboge contains about 70 per cent. of resin, sometimes termed *gambodic acid*, which forms numerous salts. Gamboge is used as a pigment, and in miniature-painting; also to tinge gold varnish. In medicine it is used as a drastic purge. It is sometimes improperly used by confectioners to colour liqueurs. An artificial gamboge, of very little value, is manufactured with turmeric and other materials.

CAMBRIC, a species of very fine white linen, first made at Cambray, in French Flanders, whence the name.

CAMEL, a machine invented in Holland, about 1688, for raising ships by the buoyant power of water. It consists of two similar hollow water-tight vessels, so constructed that they can be applied on each side of the hull of a ship. On the deck of each vessel windlasses are attached, which work the ropes passed under the keel of the vessel to be raised. When the camel is employed to raise a ship, the water is allowed to fill each half of it; and when the ship is firmly attached to the camel, the water is pumped out, and the buoyancy of the hollow vessels raises up the ship. A ship drawing 15 feet water could by this means be made to draw only 11 feet; and the largest man-of-war in the Dutch service could be made to pass the sand-banks of the Zuyder Zee. The length of one of these camels was 127 feet; the breadth at one end 22 feet, and the other 13 feet: the hollow part was divided into several compartments.

CAMLET, or CAMBLET, a plain stuff, of which there are several varieties. Some are made of goats'-hair; in others, the warp is of hair, and the woof half hair and half silk; others, again, are entirely of wool; and in some, the warp is of wool and the woof of thread. There are striped, watered and figured camlets.

CAMPHINE. [See TURPENTINE.]

CAMPHOR is the produce of the *Laurus camphora*, or *camphor laurel*, of Japan and China. The roots and wood of the tree are chopped up, and boiled with water in an iron vessel, to which an earthen head containing straw is adapted; and the camphor sublimes, and condenses upon the straw. In China, the chopped branches are boiled in water till the camphor begins to adhere to the stirrer: the liquor is then strained, and the camphor concretes on standing: it is afterwards mixed with a finely powdered earth, and sublimed from one metallic vessel into another. Two kinds of unrefined or crude camphor are known in commerce: 1. *Dutch* or *Japan camphor*, also called *tub-camphor*, from the circumstance of its being brought from Batavia (and reported to be the produce of Japan) in tubs, covered by matting, each surrounded by a second tub, secured on the outside by hoops of twisted cane. Each tub contains from 1 cwt. to $1\frac{1}{4}$ cwt., or more. It consists of pinkish grains, which by their mutual adhesion form lumps. It is of larger grain, clearer, and sublimes at a lower temperature than the second variety, which is known in commerce as *ordinary crude camphor*, *China camphor*, and *Formosa camphor*. This is imported from Singapore, Bombay, &c., in square chests, lined with lead foil, and containing from $1\frac{1}{4}$ to $1\frac{1}{2}$ cwt. It is chiefly produced in the island of Formosa, and is conveyed in junks to Canton, whence the foreign markets are supplied. It consists of dirty greyish grains. It varies in quality, but is sometimes as fine as the Dutch kind.

Crude camphor very much resembles moist sugar before it is cleaned. It is refined, and converted into the beautiful well-known article sold in the shops, by sublimation. This process is carried on in spheroidal vessels, called *bomboloes* (Fig. 418). They are made of thin flint glass, and weigh about 1 lb. each, and measure about 12 inches across. Each vessel has a short neck. When filled with crude camphor, they are imbedded in a sand-bath, and heated to a temperature of from 250° to 280°, which is afterwards raised to between 300° and 400°. About 2 per cent. of quick-lime, and 2 parts bone-black, in fine powder, are added to the melted camphor, and the heat raised,

Fig. 418.

so as to boil the liquid. The vapour condenses in the upper part of the vessel. As the sublimation proceeds, the height of the sand around the vessel is diminished. The process is completed in about 48 hours. This operation requires considerable attention and experience. Dr. Ure says :—"If the temperature be raised too slowly, the neck of the bottle might be filled with camphor, before the heat had acquired the proper subliming pitch ; and if too quickly, the whole contents might be exploded. If the operation be carried on languidly, and the heat of the upper part of the bottle be somewhat under the melting point of camphor, that is to say, a little under 350°, the condensed camphor would be snowy, and not sufficiently compact and transparent to be saleable. Occasionally, sudden alternations of temperature cause little jets to be thrown up out of the liquid camphor at the bottom upon the cake formed above, which soil it, and render its re-sublimation necessary."

The vessels being removed from the sand-bath, the mouth is closed with tow, and in this hot state, water is sprinkled over them, and they crack. When quite cold, the cake of camphor, weighing about 11 lbs., is removed, and trimmed, by paring and scraping into the form of large hemispherical cakes, perforated in the middle. In this process the lime retains the impurities and a portion of the camphor: the latter is recovered by heating the mixture in an iron pot, with a head to it, and the product is refined by a second sublimation.

In a large chemical factory near Birmingham, which the Editor was allowed to visit, the camphor-refining room contained about a dozen sand-baths, standing parallel to each other across the room, each containing about ten bomboloes. The temperature of the room was about 150°, very dry, and highly charged with vapour of camphor. This being inflammable, means are taken to obtain heat and light, without the introduction of fire into the room. Accordingly, the sand-baths are heated from baths of fusible metal, kept at the proper temperature by a furnace outside ; and, to diminish the escape of the camphor vapour, each bombolo was covered with a glass shade. Another use of this shade was stated to be, to exclude the air, which, if admitted, would cause the sublimed camphor to be opaque instead of clear. It was also stated that the essential oil is driven off from the crude camphor, before subliming.

Camphor ($C_{10}\ H_8\ O$) is a white and semi-transparent solid, (sp. gr. 0.987,) of a crystalline fracture, a peculiarly fragrant odour, and a warm, pungent, and somewhat bitterish taste, accompanied by a sense of coldness on the tongue. It is soft and tough, but can be readily pulverised if moistened with a few drops of spirits of wine. It evaporates in the air at ordinary temperatures, and gradually sublimes in close vessels, and attaches itself to the surfaces most exposed to the light. If a vessel exhausted of air, and containing a piece of camphor, be exposed to the direct rays of the sun, these crystals will be formed speedily. When small pieces of perfectly clean camphor are allowed to fall upon the surface of pure water, they rotate and move about with great rapidity, sometimes for several hours together; but if, while the camphor is rotating, the surface of the water be touched with any greasy substance, (a glass rod dipped in turpentine answers best,) all the floating particles quickly dart back, and are instantly deprived of all motion.[1] The motions of the camphor are accelerated by placing the glass in vacuo. Camphor fuses at 347°, and boils at 400°, when it may be distilled without decomposition. The density of camphor-vapour is 5.27. Camphor is sparingly soluble in water ; 1 part of camphor requiring about 1,000 parts of water for solution. This aqueous solution is named *camphor julep*. It is very soluble in alcohol, ether, acetic acid, sulphuret of carbon, and some other substances. 100 parts of spirits of wine (specific gravity 0.806) dissolve 120 of camphor, forming the *camphorated spirit* of the Pharmacopœia. On adding water to this, nearly all the camphor is thrown down, in a minutely divided state. Considerable use is made of camphor in medicine, both as an internal and an external remedy ; but it ought never to be taken internally without medical advice. A dose of two scruples appears to be sufficient to cause death.

Camphoric acid ($C_{10}\ H_7\ O_3 + HO$) is obtained by the action of nitric acid upon camphor.

CAMWOOD, a red dye-wood, obtained from the vicinity of Sierra Leone. Its colouring matter differs but little from that of Nicaragua wood.

CANAL. [See NAVIGATION, INLAND.]

CANDLE, a cylinder or slightly conical rod formed of solid fat, in the axis of which a bundle of parallel, twisted or woven fibres is enclosed.

It is necessary to the due comprehension of some of the details of candle-making to enter briefly into the chemistry of fats and oils, substances of first-rate importance to the welfare of a country, the large proportion of carbon contained in them rendering them valuable sources of food and artificial light. Most fats and fixed oils, vegetable and animal, are mixtures of two, and generally three distinct compounds, each of which taken singly has all the properties of fats. The first of these substances, called *stearine*, (from στέαρ, tallow or suet,) is solid at common temperatures ; it constitutes the solid fatty ingredient in mutton-tallow ; the second is *oleine*, (from ἔλαιον, *oleum*, oil,) and is liquid at ordinary temperatures, and down to the temperature of freezing water ; the third substance is named *margarine*, (from μάργαρον, a pearl,) on account of its mother-of-pearl lustre : it is solid at ordinary temperatures. All fats may therefore be regarded as mixtures of the fluid oleine with the solid stearine or margarine. If the solid be in larger proportion than the fluid, as in various kinds of tallow, it requires a greater degree of heat to melt it. If the fluid portion prevails, as in the oils, the melting point is lowered.

(1) In the year 1837, the Editor contributed a paper to the "Magazine of Popular Science" on "The rotatory motion of camphor upon the surface of water," in which the opinions of many eminent philosophers on this subject are brought together. Raspings of cork, steeped in sulphuric ether, sublimated benzoic acid, potassium, and some other substances, also rotate and move about on the surface of water.

Each of these three substances contains an organic base, or substance capable of uniting with acids to form (in most cases) a neutral compound. This base is named *glycerine* or *hydrated oxide of glyceryl*,[1] and is united with an unctuous substance which has acid properties. The glycerine is common to all the three fatty principles, but the acid in each has its own peculiar characters. Thus, the acid in *oleine* is named *oleic acid*, which combining with the oxide of glyceryl of the oleine, forms *oleate of glycerine*. So also the acid of *stearine* is called *stearic acid*, which in combination with the oxide of glyceryl of the stearine forms *stearate of glycerine*. Again, the acid of *margarine* is called *margaric acid;* this combining with the oxide of glyceryl of the margarine forms *margarate of glycerine*.

All these fatty compounds are decomposed by free alkalies, such as potash and soda; their acids quitting the glycerine to unite with the alkalies, forming a soluble soap, while the glycerine is left behind in the mother liquor. The hard soaps of commerce when made with oils (palm and cocoa-nut oils excepted) are chiefly mixtures of oleate and margarate of soda, with little if any stearate. When the hard soaps are made with animal fats, they are mixtures of oleate, stearate and margarate of soda. [See Soap.]

The chief material used in making candles is tallow. This substance is the concrete fat of oxen, deer, sheep, and other large quadrupeds, separated from the fibrous matter which accompanies it. There are two principal varieties of tallow, arranged according to their purity and consistence into *candle* and *soap tallow*. It is generally sufficiently pure for soap-making without previous preparation. The supply is made up by home slaughter, and also by importation, chiefly from Russia, which supplies us every year with no less a quantity than 60,000 or 70,000 tons. A large quantity is also sent from Australia and from the states of Rio de la Plata. The importation of tallow is still on the increase.

Candles are also made in very great numbers from palm oil. This substance is obtained from the western coast of Africa, south of Fernando Po, from the fruit of the oil palm (*Elais guineensis*). The fruit externally is of a golden yellow colour, and about the size and shape of a pigeon's egg. Its fleshy covering is detached from the kernel and bruised into a paste, which being agitated with boiling water, the oil rises to the surface and concretes as it cools. Fresh palm oil is of an orange yellow colour, of a sweetish taste, and of an odour resembling that of violets. Its melting point is 81°, but after the oil has been kept some time it melts at 90° or 96°. The oil becomes rancid by exposure to the air, and glycerine and fatty acids are liberated. It contains about two-thirds of its weight of a peculiar white solid fat, which has been named *palmitine*, the remainder consisting chiefly of oleine. Upwards of 25,000 tons of palm oil are annually imported into this country in exchange for goods of British manufacture. This trade, profitable alike to Africa and to Great Britain, has also a favourable effect in checking the slave trade, the services of the natives at home being required for preparing the oil.

Such are the chief materials used in the manufacture of candles. Ordinary candles are made of tallow, and are either *dipped* or *moulded*. Mutton-suet with a proportion of ox-tallow is used for mould candles, which are required to be hard, and to have a glossy surface. Coarse tallow is used for *dips*. The first operation in candle-making is to sort and melt the tallow, and this should be done as soon as possible after the fat has been removed from the carcass, because the fibrous and fleshy substances mixed with it promote putrefaction. The tallow is usually melted in an open copper exposed to the direct action of the fire, and after fusing for a considerable time, the membranous matters collect at the surface. These are removed, and after the fat has been squeezed out at a press, they form *greaves* or *cracklings*, sometimes used for feeding dogs. The melted tallow is passed through a sieve into another copper, where it is washed with a quantity of boiling water. The impurities settle down with the water at the bottom of the copper, and the purified tallow is lifted out in buckets of tinned iron into tubs, where it cools and is ready for use.

In the method adopted in France and on the Continent for extracting the fatty matters from the cells or tissues in which they are confined, the direct action of fire is not employed, but the simple agency of steam combined with dilute sulphuric acid. The fatty matter is left to macerate for a day or two with very weak oil of vitriol, after which about 400 lbs. are taken out of the macerating tubs, and put with 24 gallons of water and 7 lbs. of sulphuric acid (specific gravity 1.845) into proper wooden vessels, where the mixture is subjected to a jet of steam, which soon causes the whole to boil. Under the influence of heat and of the weak vitriol, the nitrogenated tissue which envelopes the grease is rapidly destroyed, and the liberated fatty matter floats on the surface of the boiling water perfectly free from all foreign matters; after which the jet of steam is stopped, and the tallow is let off by a tap into a proper receiver. The simple addition of a little vitriol re-prepares the melting vessels to receive a new charge of macerated fat, which also becomes fit for letting off after a short time.

Larger pans are required than those used in England to do the same amount of work; but the operations are performed more quickly. From 100 lbs. of fatty matter 85 lbs. of tallow are produced by this method, whilst the more dangerous one now practised gives only 82 lbs., so that the manufacturer gets three per cent. more tallow by the above process, which amply repays him for the $5\frac{1}{2}$ lbs. of scraps which are in a great measure lost. But the animal matters remaining in the pan can be used as manure, or, by mixing them with saw-dust, as fuel. This method renders tallow-melting safe, and gets rid of

(1) The oxide of glyceryl, at the moment of its liberation, unites with water. This acid has not been insulated. If it were so, it would bear the same relation to glycerine as ether does to alcohol.

that most disagreeable odour which characterises the neighbourhood of tallow-melting establishments.

The wicks used for the best candles are cotton rovings imported from Turkey. Four or more skeins, according to the thickness of the wick, are wound off at one time into bottoms or clues, and afterwards cut to the proper lengths, being first doubled and twisted so as to leave a loop at one end. Wicks for dip candles are also cut very expeditiously by machinery. Balls of cotton previously made into a loose roving or cord, consisting of a dozen or more threads each, and differing in thickness according to the size of the candles, are put into a box or drawer. The ends are then attached to a rod or broach, and equal lengths of cotton are cut off by drawing a knife along a whole range of them at once, a slight twist being given to the whole of them by the action of the machine. When the wicks are cut to the proper length they are dipped into melted tallow and rubbed between the palms of the hands; and on being left to harden they are arranged upon smooth sticks or broaches about half an inch in diameter and three feet long, for the purpose of dipping. The dipping-room contains a boiler for melting the tallow, a dipping-mould or cistern, and a large wheel for supporting the broaches. A long balance-shaped beam is suspended from the ceiling, to one end of which is attached a wooden frame for holding the broaches with the wicks properly arranged. The opposite end of the beam has a scale-pan with weights to counterbalance the wooden frame, and to enable the workman to determine the size of the candles. The end of the lever which supports the frame is situated just above the dipping-cistern, so that by gently pressing down the balanced beam, the wicks descend into the melted tallow, Fig. 419, which is kept in a

Fig. 419. DIPPING.

proper state of fluidity by a brazier or a bath of hot water on the outside. The wicks are dipped three times for the first *lay*, and after being kept a short time over the cistern for the wicks to drain, the sticks are placed on a rack, and the candles are left to harden. The same process is repeated a second and third time, or oftener, according to the required weight of the candles, a sufficient time being allowed between each dipping for the tallow to consolidate; hence the dipping-room requires to be kept cool; for which purpose the business of candle-making is confined to the cooler months of the year; but if carried on in summer, the cooler part of the night is the time preferred.

Dr. Ure describes a machine for dipping candles, which has long been used at Edinburgh. For the details of this machine we must refer to his Dictionary, article CANDLE. It consists essentially of a strong upright post, turning upon pivots, and supporting a wheel with 12 horizontal arms, from the end of each of which is a frame or *post* containing 6 rods, on each of which are 18 wicks, making altogether 1,296 wicks. On turning the wheel round, each post is brought in succession over the dipping-mould, and the wicks receive a fresh coating. The constant motion through the air tends to consolidate the tallow, and it is stated that in moderately cold weather, a wheel of common-sized candles can be finished in two hours.

The moulds used in making mould candles are of pewter, and consist of two parts; namely, a hollow cylinder of the length of the candle open at both ends, and nicely polished on the inside; and a small metallic conical cap with a hole in the centre for the wick. Glass moulds have also been lately introduced. 8 or 12 of these moulds are fixed in a wooden frame, the upper part of which is a trough, into which the open extremities of the moulds are inserted on a level with its surface, so that the tops of the moulds point downwards. In order to insert the wicks the frame is placed on its side, and the man introduces a hooked wire into the mould, and passing it out through the point at the top attaches to it the loop of a wick, a number of which he holds in his left hand; he then draws back the wire, and brings the wick along with it. All the moulds being thus provided, another man passes a small wire through the loop of each wick, for the purpose of keeping it stretched in the centre, or along the axis of the cylinder. The moulds are filled by running tallow into the trough from a boiler kept at the proper temperature, and furnished with a cock or tap. When the moulds are almost half filled the supply of tallow is cut off, and the workman laying hold of the portion of each wick that projects from the point pulls it tight. This prevents the wick from curling, and secures it in its proper position. The filling is then completed, and the frame put aside to cool. The candles ought to remain in the moulds until the next day, but it is known when they are properly set by a snapping noise produced by pressing the thumb against the bottom of the moulds. When this occurs the wires are pulled out, the superfluous tallow is scraped off with a small wooden spade; a bodkin is introduced into the loop of the wicks, and the candles are withdrawn in succession. They are then removed to the storehouse, where in the course of a few months they become sufficiently white for sale. No duty is now paid on candles.

The tallow used in moulding is sometimes melted over a solution of alum, the sulphuric acid of which

appears to act as a purifier. The proper consistence for moulding is judged of by the appearance of a scum on the surface, which forms in hot weather between 111° and 119° Fahr.; in mild weather at 108°, and in cold at about 104°.

Wax is not adapted for moulding, in consequence of the contraction which it undergoes in cooling, and the tenacity with which it adheres to the sides of the moulds. Wax candles are made in the following manner:—A set of wicks properly cut and twisted, and warmed at a stove, are attached to a ring of wood or metal, and suspended over a basin of melted wax, which is taken up by a large ladle and poured on the tops of the wicks, each wick being kept constantly twisted round its axis by the fingers; the wax in running down adheres to the wicks, and completely covers them. This process is repeated at intervals until a sufficient thickness is attained. The candles are then rolled while hot with a flat surface of box-wood upon a smooth table of walnut-wood kept constantly wet; this makes them truly cylindrical. This basting, twisting of the wicks and rolling is sometimes repeated two or three times before the candles are finished, but a skilful workman will cover the wicks with the proper quantity of wax without taking them down. If a wax candle be broken across, the annular layers, like the yearly rings in wood, can be easily counted, and their number indicates the number of times the wax has been poured over the wick.

The large wax candles used in Roman Catholic churches are made by placing a wick upon a slab of wax, bending this together and then rolling it.

The long, thin, coiled wax tapers are made in the following manner:—the wick, which must be uniform, is wound round a drum, from which it is passed into the wax pan, at the bottom of which is fixed a guiding roller, and from thence through a drawing plate to a second drum. The drawing plate is of metal, and is similar to that used in wire-drawing: the holes in it correspond in size to the diameter of the taper, and the wick is passed through smaller and smaller holes until it is of the proper thickness.

Rush-lights are made in the same manner as dip candles. The Rev. Gilbert White, in his "Natural History of Selborne," describes the method of making them by the cottagers of Hampshire. He says:—"The proper species of rush for this purpose seems to be the *juncus effusus*, or common soft rush, which is to be found in most moist pastures, by the sides of streams and under hedges. These rushes are in best condition in the height of summer; but may be gathered, so as to serve the purpose well, quite on to autumn. It would be needless to add, that the largest and longest are best. Decayed labourers, women, and children, make it their business to procure and prepare them. As soon as they are cut they must be flung into water, and kept there; for otherwise they will dry and shrink, and the peel will not run. At first a person would find it no easy matter to divest a rush of its peel or rind, so as to leave one regular, narrow, even rib from top to bottom that may support the pith: but this, like other feats, soon becomes familiar even to children; and we have seen an old woman, stone blind, performing this business with great despatch, and seldom failing to strip them with the nicest regularity. When these *junci* are thus far prepared, they must lie out on the grass to be bleached and take the dew for some nights, and afterwards be dried in the sun.

"Some address is required in dipping these rushes in the scalding fat or grease; but this knack also is to be attained by practice. The careful wife of an industrious Hampshire labourer obtains all her fat for nothing; for she saves the scummings of her bacon-pot for this use: and if the grease abounds with salt, she causes the salt to precipitate to the bottom, by setting the scummings in a warm oven. Where hogs are not much in use, and especially by the sea-side, the coarser animal oils will come very cheap. A pound of common grease may be procured for four-pence; and about 6 lbs. of grease will dip a pound of rushes; and one pound of rushes may be bought for one shilling; so that a pound of rushes, medicated and ready for use, will cost three shillings. If men that keep bees will mix a little wax with the grease, it will give it a consistency and render it more cleanly, and make the rushes burn longer: mutton suet would have the same effect. A good rush, which measured in length 2 feet $4\frac{1}{2}$ inches, being minuted, burnt only 3 minutes short of an hour. These rushes give a good clear light. Watch lights (coated with tallow) it is true shed a dismal one, 'darkness visible;' but then the wicks of those have two ribs of the rind or peel to support the pith, while the wick of the dipped rush has but one. The two ribs are intended to impede the progress of the flame and make the candle last.

"In a pound of dry rushes, avoirdupois, which I caused to be weighed and numbered, we found upwards of 1,600 individuals. Now suppose each of these burns, one with another, only half an hour, then a poor man will purchase 800 hours of light, a time exceeding 33 entire days, for three shillings. According to this account, each rush before dipping costs $\frac{1}{33}$ d of a farthing, and $\frac{1}{11}$ th afterwards. Thus a poor family will enjoy $5\frac{1}{2}$ hours of comfortable light for a farthing. An experienced old housekeeper assures me that $1\frac{1}{2}$ lb. of rushes completely supplies his family the year round, since working people burn no candle in the long days, because they rise and go to bed by day-light. Little farmers use rushes much in the short days, both morning and evening, in the dairy and kitchen; but the very poor, who are always the worst economists, and therefore must continue very poor, buy a halfpenny candle every evening, which in their blowing open rooms does not burn much more than 2 hours. Thus have they only 2 hours' light for their money, instead of 11." [1]

(1) It will be remembered that these observations were written in the year 1775. Since that time tallow has become much cheaper, and the trade of candle-making has risen to the dignity of a manufacture, which, together with the repeal of the duty on candles, has had the effect of considerably lowering the price.

Considerable improvements have been made of late years in the manufacture of candles, by decomposing the fatty or oily substances used for the purpose, and employing the stearine (stearic acid) or palmitine (palmitic acid) only. We will first describe the processes adopted in the manufacture of stearine candles, taking as our chief authority, the account given by M. Dumas in the sixth volume of his "Traité de Chimie appliquée aux Arts." (1843.)

If the reader will again refer to the constitution of fatty substances as stated at the commencement of this article, the following details will be intelligible.

The first process consists in destroying the combination of the fatty acids with the glycerine by means of lime which displaces it, whereby stearate, margarate, and oleate of lime, are produced in the form of a solid soap, and the glycerine set at liberty is dissolved in the water necessary to determine the combination. The lime must be as caustic as possible, and be thoroughly incorporated with the fat. For this purpose, about 1,100lbs. of fat are placed in a vessel of wood, slightly conical and of the capacity of about 100 gallons, together with a quantity of water sufficient to dissolve the glycerine: this will be about 50 gallons. The temperature of the whole is raised by introducing a jet of steam into the vessel, and when the fat is melted, about 170 lbs. of lime well mixed up with water are added, and the whole well stirred up by machinery until the chemical changes shall have been effectually produced. Figs. 420, 421, show the arrangements of this vessel in

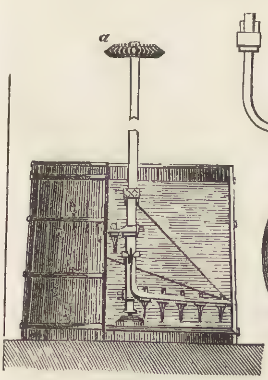


Fig. 420.

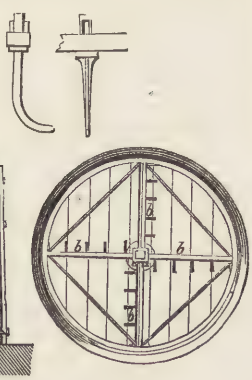


Fig. 421.

section and plan. A central axis, which is connected at *a* with the moving power of the establishment, carries a number of horizontal arms, *b b*, furnished with teeth or cutters, shown on a larger scale above. The brisk motion of this stirrer causes the lime to combine with the fatty acids in a shorter time and with a less quantity of lime, than could be effected by stirring by hand labour. At the end of 6 or 8 hours, the saponification is complete; the liquid portion containing the glycerine in solution is drawn off, and the stearate, margarate, and oleate of lime, are then removed in the form of very hard soaps.

The next process is to separate the lime from the fatty acids: this is effected by means of dilute sulphuric acid, for which purpose, the weak acid as it leaves the sulphuric acid chambers, answers very well; hence the manufacturers of stearine find an advantage in having their works in close proximity to sulphuric acid works, or even in manufacturing the acid themselves, as the expensive process of concentration can be entirely dispensed with. [See SULPHURIC ACID.]

In order that the acid may act effectually upon the soaps, it is necessary that they should be reduced to powder. In some works this is done roughly by hand labour; but it is much more economical to supply machinery, such as grooved cylinders, kept constantly cool by a current of water passing through them, otherwise the soap in passing between them would raise the temperature, and form into laminæ instead of powder.

The vessels in which the decomposition is effected resemble those used for the saponification, except that

Fig. 422. STEAM BOILING VATS.

they are lined with lead to preserve the wood from the action of the sulphuric acid. They are heated by a jet of steam or by a coil, and are furnished with an agitator. An excess of sulphuric acid is used to ensure the complete saturation of the lime, which forms a solid sulphate of lime, and sets the three fatty acids at liberty. The decomposition is effected in about 3 hours. The mixture being then left quiet, the fatty acids float on the surface, and the sulphate of lime falls to the bottom of the vessel. The fatty acids are drawn off by means of a stop-cock at the side, into a wooden vessel lined with lead, and heated by means of steam. The last traces of the lime are removed by washing with a very dilute solution of sulphuric acid. The fatty acids are next washed in another vessel with pure water, and are then drawn off into moulds of sheet-iron, the sides of which slope in towards the bottom, in order that they may deliver the cake of solid acid more readily.

When the moulds have become cold, the cakes, weighing about 60 lbs. each, have a yellow tint and a greasy appearance, both which defects arise from the mechanical mixture of the liquid oleic acid, with the crystals of the solid stearic and margaric acids. The fluid acid is got rid of by subjecting the mass to strong pressure. For this purpose the cakes are cut up into slices by means of the machine shown in Figs. 423, 424. A knife *e* is let into one of the radii of a fly wheel, which is mounted on a horizontal axis, and moved by a strap passing over a fast and loose pulley, *k*. The motion of this axis also sets in motion an endless band *i*, on which the solid cake is placed, and by this means is brought up to the knife to be cut. It will be seen that the endless screw *f* on the axis of the fly gives motion to the toothed wheel *g*, and this in

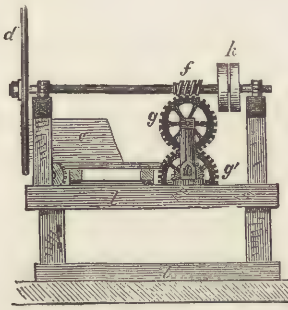


Fig. 423.

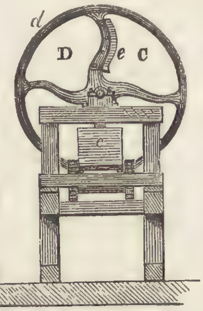


Fig 424.

its turn to *g'*, which carries on its axis one of the rollers on which the endless band is made to move. These toothed wheels are so arranged that for every turn of the fly *d*, and consequently of the endless screw *f*, the cake *c* advances through a space equal to that of one of the slices cut off; and it is evident that whatever be the rate of motion of the fly, the slices will always be of the same thickness. The endless band is supported by a fixed plank to prevent it from being warped by the weight of the cakes.

As soon as the cakes are cut up, the slices are arranged in thin layers in bags of serge or on mats piled one above another. These are arranged on the stage of a hydrostatic press, and subjected to great pressure. A large portion of the oleic acid escapes with pressure only, but for the remaining portion, as well as for the margaric acid, the pressure must be assisted by heat. For this purpose the bags or mats are placed between strong, hollow, shallow boxes covered with felt, and filled with steam by means of jointed pipes, which admit of being lengthened or shortened without interfering with the supply of steam. The oleic acid is received into a vessel, where it deposits a quantity of stearic acid, which the high temperature has assisted in bringing over. This fluid acid is used in soap-making, and as a cheap oil for variegated lamps, and other purposes. The solid stearic and margaric acids are pressed a second time, after which they appear of a brilliant whiteness, and form more than 45 per cent. of the fat employed. They are then taken to vats, where they are further purified with very dilute sulphuric acid, which removes all remaining traces of lime and other impurities; and lastly, the sulphuric acid is removed by repeatedly washing with water. The vats in which these operations are conducted are all heated by means of steam, or have steam-jackets as in Fig. 425. After reposing for a time, the fatty acids are decanted into a lower vat containing pure water, which is frequently renewed. They are again left to repose, and are finally drawn off into moulds, in which the cakes are formed of a perfectly white colour, and fit for the manufacture of candles.

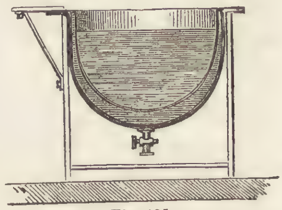


Fig. 425.

Palm oil, as already stated, is extensively used in the manufacture of candles. In order to obtain the beautiful white acids of which candles are now made, several plans have been adopted, of which the following is an outline. The oil, which is of an orange yellow colour, is bleached by exposure to the air in large shallow backs, or vessels similar to brewers' coolers. Water to the depth of 7 or 8 inches is first let into the backs, and this is raised to about the temperature of boiling water by means of coils of pipes filled with steam. The oil is then added, which soon melts and diffuses itself in an equable layer over the surface of the hot water. This layer ought not to be more than $1\frac{1}{2}$ or 2 inches thick. By the united action of air, light, and a high temperature, the bleaching proceeds rapidly, and is completed in about 10 or 15 hours. The oil still has a slight reddish tint, and when cold is of a dirty white colour. In this state it is well adapted to the manufacture of an excellent white soap of great hardness. For the manufacture of candles it is put into woollen bags, and subjected to strong compression in a hydrostatic press, first at a temperature of about 55°, and a second time at the temperature of about 86°. The solid matter which remains is melted in a vessel containing a coil of pipe heated by steam. After resting for a time it is decanted, and 6 per cent. of wax is added. It is then fit to be employed in the manufacture of mould candles.

Davidson's method of bleaching palm oil consists in first melting it in an iron vessel lined with lead, with the addition of from 6 to 11 per cent. of chloride of lime previously mixed with 12 parts water. The ingredients are thoroughly incorporated, and left to become cold. The cakes thus formed are cut up into small pieces, and exposed to the air for two or three weeks. The chlorine which is liberated slowly bleaches the oil. The lime is then separated by dilute sulphuric acid, which disengages the remainder of the chlorine, and completes the bleaching. The objection to this process is, that the chlorine at a high temperature attacks the oil, decomposes the palmitic acid, and itself takes the place of the hydrogen of the acid.

Palm oil has also been bleached by the use of oxygen. The oil is mixed with $\frac{1}{16}$th of finely powdered manganese; boiling water equal to half the weight

of the mixture is then added, and with constant agitation strong sulphuric acid equal to $\frac{1}{32}$d of the weight of the oil is poured upon the mixture. The mass is then allowed to cool. The solidified fat is of a greenish hue, but soon becomes white by exposure to air and light.

Palm oil poured slowly over a heated iron plate absorbs oxygen from the air with the evolution of an acid vapour, and becomes converted into a clear colourless fat. The colouring matter begins to decompose at the temperature of 230°, and when this heat has been attained over an open fire, the temperature is maintained by the introduction of a current of high-pressure steam, and the decomposition is promoted by constant stirring. 4 tons of palm oil can thus be decolorized in 10 hours.

The most complete and rapid, but also the most expensive method of bleaching, is by the use of bichromate of potash, and strong mineral acids. This is Watt's method, and consists in an oxidation of the colouring matter by chromic acid. The oil is first melted, and allowed to stand to deposit its mechanical impurities. The clear oil is then drawn off into wooden vessels, mixed with a concentrated solution of 25 lbs. of bichromate of potash, 8 lbs. of sulphuric acid, and about 50 lbs. of strong muriatic acid to the ton of oil. The whole is well stirred together. (Instead of muriatic acid, common salt with an additional quantity of sulphuric acid may be used.) In a few minutes the light green appearance of the oil, and the rising of a thick scum to the surface, indicate the completion of the process. It can readily be seen by the colour of specimens allowed to cool, whether a sufficient quantity of the bleaching material has been used. In this process, the sulphuric acid combines with the potash, and liberates the chromic acid, which parting with half its oxygen to destroy the colouring matter becomes converted into oxide of chromium. The muriatic acid forms a soluble compound with this green oxide, chloride of chromium. The bleached oil has now to be separated from the aqueous solution of chloride of chromium, (and of sulphate of soda when common salt has been used.) This separates as the heavier liquid upon which the oil floats when the warm mixture is allowed to repose during half an hour. The fat collected from the surface is then washed in a second vessel with water made to boil by a current of steam. The process of bleaching 1 ton of oil does not occupy more than 5 minutes, and the cost is about 16*s.* 6*d.* per ton.

The most extensive factory in this country of candles made from the bleached solid fat of palm oil is that of Price's patent candle Company at Belmont, Vauxhall. From a statement published in the Illustrated London News, and also from information furnished to the Editor during his visits to the factory, we learn that this Company working day and night employs above 700 hands, in addition to steam and hydraulic power, and consumes upwards of 4,000 tons of palm and cocoa-nut oil per annum. There are also branch works at Battersea The oil is imported in large casks or tuns, and on arriving at the works, a steam-pipe is introduced into each, which has the effect of rendering the contents fluid. The oil thus liquefied is of a bright orange colour, and is conveyed through a pipe to reservoirs, where it is subjected to a chemical treatment similar to that already described for extracting stearine from animal fat. A part only of this process is conducted at Vauxhall; the remainder is performed at Battersea. The transit of the raw material (so to speak) between the two factories is managed by means of barges. When the material is returned to Vauxhall it is in the form of large cakes or lumps, which are cut into slices by means of a revolving cutter as before explained, Fig. 423. The solid cake is brought up to the cutter by means of an endless band, and the slices as they are cut off fall down a tube arranged like the tube of a telescope, so as to be shortened or lengthened at pleasure. At the bottom of this tube

Fig. 426. SPREADING AND STRIPPING.

is a carriage provided with two heavy rollers, moving backwards and forwards through a space equal to that which two of the cocoa-fibre mats on which the fatty acids are spread would occupy when placed side by side. A mat is placed so as to occupy one half of the solid table on which the carriage moves; the first action of the rollers is to bring down a balanced iron frame upon the margins of the mat; the fat is then, by the action of the rollers, spread equally over the mat within the frame. The carriage then passes to the other half of the table, where a mat is covered in the same manner, and in clearing the first mat the balanced frame rises up and releases the covered mat, which is removed by an attendant, and a new mat is thrown down in its place. By the time the second mat is covered, and the place of the first mat occupied by the third, the carriage is moving towards the third, and releasing the second. In this way the mats are

quickly and equably covered, the space of an inch being left along each of the four edges of the mat in order that when these mats are piled up in the hydraulic press, the intense pressure may not force the

Fig. 427. HYDRAULIC PRESS-ROOM.

fatty matter out over the edges. These mats are piled up on trucks, and conveyed to the pressing department, Fig. 427, which contains 42 powerful hydraulic presses, the pumps of which are worked by steam power. When placed in the press an iron plate is introduced between each pair of mats for the purpose of giving greater stability to the pile. In the first pressure as much oleic acid is removed as can be got out at the ordinary temperature. The second pressure takes place at the temperature of 120°. The mats are then taken to the stripping bench, Fig. 426, where the cake, now reduced to a dry, solid, white substance, moulded to the surface of the mat by the intense pressure, is stripped off by hand. It is not, however, sufficiently white and pure for the purpose of candle-making. In the course of pressing and pulling about it has contracted iron-moulds and other impurities. It is therefore conveyed to the vats, Fig. 422, where it is washed in a hot solution of very dilute sulphuric acid.

After this, the fatty acids are conveyed to the candle-moulding department, the arrangements of which are on a very extensive scale. A long apartment, well lighted and ventilated, is occupied by double lines of railway, upon which the moulding-frames are moved. Beginning at the end of one of these lines of railway, we have both the commencement and the end of moulding a set of candles. Each moulding-frame is furnished with a tin box, containing 18 reels, and upon every reel is wound 60 yards of plaited cotton wick. The ends of these wicks are passed through eyes at the top of the moulds, and are held above the upper part of the moulding-frame by a set of forceps. By a very beautiful contrivance, the mechanism which expels the candles from one set of moulds draws in the cottons ready for the next filling. In Fig. 428 the workman at the end of the railway is in the act of separating the candles and rewicking the moulds. This being done, a lateral motion is given to the frame, whereby it falls from the horizontal into a vertical position, with the trough upwards, ready for filling, and is transferred from the left to the right-hand line of rails. A boy pushes the frame forward, and this in its turn is pushed forward by other frames succeeding, until it arrives at a hot closet, where it attains the temperature necessary for filling. If the moulds are filled at the ordinary temperature of the air, the fluid fat forms into large irregular crystals, giving the surface of the candle an unpleasant speckled appearance. It was found that by the addition of a small portion of arsenic, the crystals became more broken up, and the fat solidified in a homogeneous manner; but the use of arsenic being so very objectionable, and evident to the senses by the smell of garlic, whenever a candle was blown out, candles containing that poisonous compound fell deservedly into disrepute. It was found, however, that simply by heating the moulds before

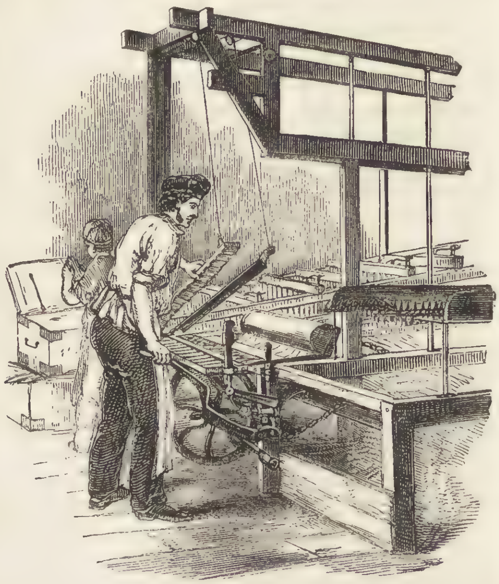


Fig. 428. MOULDING-FRAME.

filling, and pouring the fat at a temperature only just sufficient to maintain it in the fluid state, the fat solidified in a regular manner. On leaving the hot closet, the frame, the progress of which we are following, arrives at a cistern containing the melted fat, kept at the proper temperature by means of a coil of pipe filled with steam. A man then opens a hatch, when the fat flows out through as many holes as there are moulds to be filled: the fat flows into the moulds, completely filling them, as well as the trough into which their open ends are inserted. The fat soon solidifies. A boy then detaches the forceps, which kept the wicks tightly strained; scrapes out the superfluous tallow from the trough, by means of a wooden wedge; moves the frame into a little carriage at the further end of the line in which it was filled, and then wheels this carriage to the further end of the line from the near end of which we started. Other frames, succeeding the one we are following, push it forward until it gets back again to the place

from which we commenced. The man takes hold of the frame, lifts it up into a horizontal position, moves a lever, which operates upon a set of ramrods provided with a spring-catch, which lays hold of the mould tops, and pushes them, with the candles attached, through the moulds; and thus, by a single operation, one set of candles is drawn and the wicks for the next set inserted. The candles thus ejected in parallel lines are received upon a grooved board; a board covered with flannel is brought down upon them; the spring forceps are inserted, to hold the wicks securely; and a circular knife passed between the candles, and the forceps finally separates the made candles from the wicked moulds. The candles are then removed; the frame is transferred from the left to the right-hand line of rails, and the round of operations commences as before. It is stated that in each set of moulding-frames constituting a candle-machine there are, when first cottoned, 92 miles of wick; so that, if the six machines contained in this department were started at once, above 500 miles' length of candles would be made in exhausting one single wicking of the machines.

The candles, as they are released from the moulds by the drawing-machine, are conveyed in boxes to the packing department, where they are put up in sealed packets with great rapidity. The people are so accustomed to this work that, whatever be the number of candles required for one packet, they take them with one grasp from the heap, without any kind of mistake.

The manufacture of *night-lights* is a very important feature in this establishment. A night-light consists

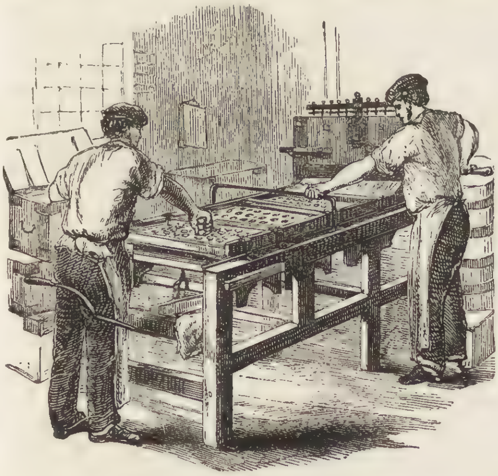


Fig. 429. MAKING NIGHT-LIGHTS.

of a very short thick cylinder of fat, with a very slender wick, and is calculated to burn for 6, 8, 9, or 10 hours. There are three kinds of night-lights, namely, *Patent Alberts, Child's night-lights,* and *Price's patent night-lights.* The first are formed in a metal frame, containing a number of cylindrical holes: at the bottom of each hole is a projecting wire, which moulds a narrow hollow tube for the wick, which is inserted by an after process. The trough containing the cylindrical holes is filled with the melted fat, as shown in Fig. 429. When this has become solid, the superfluous fat is scraped off: a man then depresses a lever, which causes the bottoms of the moulds to rise and eject the cylinders of fat. The wicks are then inserted, with marvellous rapidity, by a number of children. Each wick is stiffened with wax, and has a small piece of tin as a support at the bottom. The wick is put through the hole, and the tin cemented to the bottom by dashing it down upon a small glazed earthenware vessel, kept hot by the burning of a light within. These lights are burnt in glasses similar to a fluted straight-sided wine-glass. Judging from the number of little lads employed in "wicking," there must be a great demand for these lights, which is certainly justified by the whiteness and clearness of the material, the absence of smell of any kind, their elegant appearance while burning, and their perfect safety.

In the preparation of *Child's night-lights,* a paper box like a pill-box, with a hole in the bottom, is first made: into this is inserted a waxed wick, provided with a tin support at bottom; the box is then filled up with material, and put out on boards to cool. This is apparently a simple process; but it requires considerable care and accuracy. Great difficulties were originally experienced in compounding the material, and in regulating the small wick, so as to burn the required time in both warm and cold weather. In using these lights, they are placed in a saucer containing water to the depth of about one-eighth of an inch, not only for the sake of security, but also to keep the bottom cool, and thus prevent the fat from running out of the case.

Price's patent night-lights are made like the last, but of a somewhat cheaper material, which has been patented. They are intended to be introduced among the working classes, and to be sold at the cheap rate of two for a penny. At the time of our visit, the manufacture of them had just commenced.

We were shown the building appropriated by the Company to the manufacture of night-lights; and when it is stated that it is 180 feet long by 100 wide, some idea may be formed of the extent of this branch of manufacture.

In concluding our notice of this factory, it should be stated that everything seems to be in perfect order; the health, comfort, and convenience of the numerous workpeople are consulted; there is an excellent school for the children, who attend a certain number of hours every day. The furnaces consume their own smoke, and are adapted to the burning of the refuse coal of the market. Connected with the establishment is a laboratory, an engineer's workshop, carpenters', tinmen's, coppersmiths', and weavers' shops, forges, a cooperage, a sealing-wax manufactory, and a steam printing-machine, for printing labels, &c. The buildings are waterproof; and the smell of the manufactured material reminds the visitor of violets rather than of tallow.

We may appropriately conclude this article with a few remarks on the chemistry of a candle. Flame has been defined to be a luminous bubble of gaseous

matter. It is not, however, necessarily luminous; for the flame of pure hydrogen has but little illuminating power, although its heat is great. If, however, we project into the hydrogen flame solid matter in a minutely divided state, such as charcoal dust, steel filings, oxide of zinc, magnesia, &c., the solid particles become white-hot in passing through the flame, and greatly improve its luminosity. In the flame of our candles, lamps, and gas-lights, hydrogen supplies the heat, and minutely divided carbon the light. A candle is a simple but ingenious contrivance for supplying the flame with as much melted fat as it can consume without smoking; and, to produce this effect, the wick must bear a certain proportion to the thickness of the candle. If the wick be too large, too much tallow will be melted, and the candle will gutter; if too small, too little tallow will be melted, and the flame will gradually be inclosed within a circular wall, which being from time to time undermined by the heat, will fall down, and also cause the candle to gutter. In night-lights, there is indeed a small wick and a great thickness of tallow, whereby a deep and full reservoir of melted fuel is formed; but this is prevented from escaping by the paper mould which surrounds it. If the thickness of the candle be properly adjusted to the size of the wick, the tallow immediately below the flame is melted into the form of a hollow cup, which forms a reservoir always properly filled for feeding the flame. The fibres of the twisted wick act as a congeries of capillary tubes, which convey the fluid fat into the flame, where, being exposed to a high temperature, and sheltered from the air by the outer shell of flame, it becomes subjected to a dry distillation. The inflammable vapour thus produced rises, and, by constant combustion, diminishes in quantity, and consequently in diameter, until at length it entirely disappears in a point.

We have spoken of flame as a luminous bubble or shell, because it is in fact a hollow body, the exterior only being luminous, where the contact with the air produces perfect combustion. A current of air, set in motion by the heat of the flame, causes fresh air constantly to stream up from below: the oxygen of the air, aided by the high temperature, decomposes the inflammable vapour of the fat into hydrogen and carbon: the hydrogen burns, or, in other words, unites with the oxygen of the air, and forms vapour of water: the carbon at the same moment is set free, becomes white-hot, and imparts luminosity to the flame, but it does not disappear from the scene of action until it gets to the exterior of the flame, where the oxygen of the air seizes it, and forms with it carbonic acid.

The flame of a candle, Fig. 430, consists of four tolerably distinct portions:—1. the dark interior, containing unburnt combustible vapour; 2. around this the brilliant part of the flame, or the flame properly so called, where the hydrogen is united with the oxygen of the air, and the carbon, not having yet done so, is in an incandescent state; 3. beyond this another film or casing, where the oxygen of the air unites with the carbon; 4. the blue portion at the bottom of the flame, where the inflammable vapour undergoes perfect combustion, and no solid carbon is deposited to afford light. In some cases there is, 5. a slender cone of a deep red colour, arising from an excess of carbon, which escapes unburnt, or nearly so, at the top of the flame, and cooling below a white heat, diminishes the light. This, however, never takes place in a well made candle. In this, on the contrary, the hottest part of the flame is just at the top of the luminous cone, where combustion is perfect, and the air not sufficiently in excess to carry away the heat so quickly as at the sides, or in the blue part at the bottom.

Fig. 430.

The portion of the wick within the flame is charred by the heat, but not consumed, on account of the absence of air. In a common candle it is evidently not consumed, or those troublesome and untidy implements, snuffers, would be unnecessary. In course of time, however, if the candle be left unsnuffed, the wick will project beyond the flame, and coming in contact with the air, be partly consumed; but the soot, collecting as a spongy mass at the top, will darken the flame, and at length, falling into the cup, will break down its edges, and cause the tallow to overflow. In wax, stearine, and sperm candles, this defect is avoided by plaiting the wick, or by giving it a greater twist, by which means the end is caused to bend considerably, and thus, protruding out of the flame, is consumed.[1] If this method were adopted with tallow candles, it would only produce guttering. In Palmer's candles, the wick is in two parts, and, by a particular twist given to each, and by winding a thin wire round each, they are made to fall asunder like a fork, when both ends, constantly protruding through the flame, are consumed.

The properties of flame, as above stated, may be illustrated by a number of beautiful experiments. To prove, for example, that the combustion is superficial only, and that the flame is a film of white-hot vapour, enclosing an interior portion, which cannot burn for want of oxygen, bring down upon the flame of a candle a piece of thin glass, so as to make a transverse section of the flame: we shall then observe a ring of light surrounding the interior dark part of the cone. This experiment may be still better performed by means of a piece of wire-gauze, about nine inches square, and of such fineness as to have about thirty meshes in the square inch. When this is gradually

(1) According to Dumas, stearine candles always retain a minute portion of lime, which would clog the wick, and diminish its capillarity, unless the precaution be previously taken to pass the wick through a solution of boracic acid: this forms with the lime a borate, which becomes fixed in the wick, and is converted into a fusible bead, which may be seen at the end of the wick after its complete combustion.

brought down upon the flame of a large and steadily burning wax candle, the flame will be cut off where it touches the gauze, and the exterior luminous circle will be well defined, Fig. 431. The inflammable matter of the flame will pass through the gauze in the form of smoke; its temperature being so far cooled in its passage through the meshes as to be incapable of passing through as flame. It is on this principle that the safety-lamp of Sir Humphry Davy serves as a protection in coal-mines. [See COAL.] The inflammable vapour which passes through the wire-gauze can, however, be kindled by the direct application of flame, as in Fig. 432. These experiments are well exhibited with a jet of gas, issuing under low pressure. If the gauze be held over the jet before it is lighted, and a flame be applied above, it will take fire there, and the gauze will prevent it from passing through, so as to kindle the lower half. (See Fig. 433.) Place a piece of camphor on the centre of the wire-gauze, and apply a flame below: the camphor will melt, and pass through the gauze, burning only on the under side, as in Fig. 434.


Fig. 431.

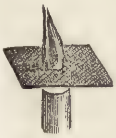


Fig. 432.


Fig. 433.


Fig. 434.

The cooling power of wire-gauze may be referred to its good conducting power: it also becomes by use an excellent radiator of heat. That flame is extinguished by cooling it may be shown by bringing a large mass of metal near a very small flame, or by carefully surrounding it by a coil of wire. The metal abstracts its heat, and extinguishes the flame. When a cold surface is held over a large flame, a portion only of such flame is destroyed, and the carbon of the inflammable vapour is deposited in the form of a minutely divided soot on the cold surface. That no combustion goes on, or can go on, in the centre of flame, may be shown in various ways; as, for example, if we kindle spirit of wine (which does not deposit carbon) in a small saucer, and place a rod of white wood across it for a few seconds: it will be found on removing the wood that it is burnt or blackened only at two points, where the flame was in contact with the air, Fig. 435. We may even place gunpowder, contained in a small circular spoon, or even at the end of a small knife, within the flame, and it will not be kindled. Phosphorus under similar circumstances will fuse, but not take fire, and oil of turpentine, in a small thimble, will become vapour, which will burn only at the upper part of the flame, where it is in contact with the air.


Fig. 435.

It will be understood, then, that the interior dark part of the flame contains inflammable vapour, which will not itself support combustion. This inflammable vapour may be drawn out of the flame and ignited at a distance from it, by inserting one end of a small glass tube into the flame of a large candle, *f*, Fig. 436: *p* is the glass tube held in an inclined position in the centre of the flame, and *g* is the inflammable vapour ignited at its extremity.

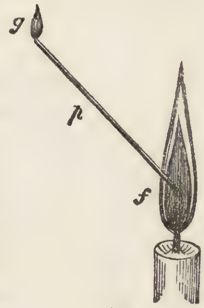


Fig. 436.

By propelling a current of air through flame, as in the blowpipe, we supply oxygen to the interior, and enable combustion to go on there as well as at the exterior, by which means the heat of the flame is greatly increased. The Argand burner acts somewhat in the same manner.

CANNON. [See CASTING AND FOUNDING—BORING.]

CANVASS, a woven fabric, made from the fibres of hemp. The word is said to be a corruption of the Latin name for hemp, *cannabis*. The Italians call it *canape*. A finer description of canvass, called *huckaback*, is made from hemp, for towels and common table-cloths. [See HEMP—LINEN—SAILCLOTH.]

CAOUTCHOUC. This very remarkable substance (also called *elastic resin*, or *India-rubber*,) is produced from the syringe-tree of Cayenne and other parts of South America. For the first knowledge in Europe of the source of caoutchouc, we are indebted to some French academicians, who were sent out for the purpose of astronomical observation, in 1735. They discovered that it was the white milky juice of certain plants, found abundantly in Para, in the Brazils, in Quito, and since found in Asia. Of late years, considerable quantities have been brought from Java, Penang, Singapore, and Assam. The trees grow so abundantly in some places, that hundreds of miles are covered with them. Caoutchouc oozes out as a vegetable milk from incisions made in the tree: it is collected chiefly in wet weather, when it flows most abundantly. The methods of inspissating and indurating it are kept secret: it appears, however, that the juice thickens and hardens gradually on exposure to the air, and that, as soon as it becomes solid, it displays an extraordinary degree of flexibility and elasticity. Hence it is supposed that the natives make moulds of clay, or some substance that can be easily broken, and cover them repeatedly with layers of the juice, allowing each layer to dry before the next is applied. When the proper thickness is attained, the mould with its elastic covering is held over the smoke of a wood fire. The mould is then broken out, and the dried bottle forms the India-rubber of commerce. Mr. Solly, in a paper on the preparation of caoutchouc, (*Trs. Asiatic Soc.*, *London*,) adverts to the manner in which the sap is prepared for the market, by being laid on to some substance in successive layers, which are allowed to dry. That such is the case is evident on cutting a bottle of caoutchouc: the layers are distinctly visible, and they may even be separated if the mass be soaked in boiling water. It is evident that a great quantity of im-

purities must be deposited on the surface, and thus diminish the force with which the layers adhere to each other, thereby taking away considerably from the value of the substance. In large masses of fresh caoutchouc, a great number of cavities filled with a brown liquid may be discovered, and these of course diminish its strength. Mr. Solly proposes that the sap as first procured should be washed with water: that which separates may then be pressed, and will be found very much stronger than if it had been prepared without the washing.

The Indians make waterproof boots of this substance, which, when smoked, have the appearance of leather. Bottles are also made of it, to the necks of which are fastened hollow reeds, so that the liquor contained in them may be squirted out at pleasure. One of these filled with water is always presented to each of the guests at their entertainments, who uses it for syringing his mouth; a custom which led to the term *seringat*, or *syringe*, being applied by the Portuguese to the tree and its resinous production. The natives also form this substance into tubes about 2 feet long, and $1\frac{1}{2}$ inch thick, which they use as torches: they give a good light, emit but little odour, and are said to last about twelve hours each.

The juice of this tree has been sent in bottles to this country. It is of a pale yellow colour, and creamy, and contains a portion of deposited caoutchouc. It has a sourish and slightly putrid odour, and a sp. gr. of 1.0117. When spread upon a solid body in thin layers, it forms an elastic deposit. It contains about 32 per cent. of caoutchouc, with a little albumen, wax, and gum, and a brown, bitter, azotised substance, soluble in water and in alcohol. When this juice is heated, the caoutchouc coagulates, and envelops the albumen. To obtain pure caoutchouc, the fresh juice must be mixed with water, and left for twenty-four hours, when the suspended caoutchouc collects on the surface in the form of a cream, which is removed, and washed repeatedly, until nothing further is separated by water: the finely divided caoutchouc is then separated from the water by the addition of a little salt or muriatic acid, and is dried at a gentle heat: as the water evaporates, the particles cohere.

The sp. gr. of caoutchouc is about 0.925. It is made hard but never brittle by cold. When boiled in water or alcohol it swells and softens, and in that state is readily acted on by those substances which dissolve it, but it is insoluble both in water and alcohol. It is soluble in washed ether, which, however, rejects the sooty and albuminous impurities, so that by precipitating a clear etherial solution by means of alcohol, the caoutchouc may be obtained in its milky form. It also dissolves in sulphuret of carbon. In cold naphtha, caoutchouc swells up into a soft pasty mass, most of which is dissolved by the further addition of naphtha assisted by heat. It also dissolves in the rectified empyreumatic oils of coal and of wood, and in the oils of turpentine, lavender, and sassafras. It is softened by and partly soluble in other volatile and many of the fixed oils, forming viscid and glutinous compounds, not drying into an elastic state, as it does on evaporating the solutions made with the above-named volatile oils, &c. A varnish well adapted for making shoes, &c. water-tight, may be obtained by boiling 4 oz. of caoutchouc in $1\frac{3}{4}$ lbs. of linseed oil until perfectly dissolved, and then passing through a strainer. The caoutchouc is to be cut into strips, and well stirred during the boiling with an iron spatula. The solutions of caustic alkalies, chlorine, and bromine, have no action on caoutchouc. Nitric acid renders it yellow, and when assisted by heat decomposes it: it is also charred on the surface by sulphuric acid. According to Faraday, the ultimate composition of caoutchouc is—Carbon 87.2, Hydrogen 12.8.

Caoutchouc melts at 248°, but when exposed to a heat of about 600°, it is resolved into a vapour which may be condensed by cold into a remarkable liquid, which has been called *caoutchoucine* or *caoutchisine*. This substance was discovered by Mr. W. H. Barnard, in the course of some experiments on the impregnation of ropes with caoutchouc, at the factory of Messrs. Enderby at Greenwich. In 1833, Mr. Barnard obtained a patent for the invention of caoutchisine, "a solvent not hitherto used in the arts." His method of preparing it is to cut common india-rubber into lumps, each containing about 2 cubic inches: these are thrown into a cast-iron still S, Fig. 437, with a cover C, ground to a metallic fit to admit a thermometer to take the temperature. F the fire place and ash-pit, E the worm-tub and worm, R a roller, and chain C, in conjunction with a crane, or other means for raising the cover to take out the residue and to charge the vessel. Heat is applied until the thermometer indicates a temperature of 600°. As this temperature is approached, a dark-coloured oil or liquid is distilled over, and nothing remains in the still but dirt and charcoal. The distillation is greatly facilitated by the addition of a portion of this oil, either previous or subsequent to the rectification, in the proportion of $\frac{1}{3}$ oil to $\frac{2}{3}$ caoutchouc. The dark-coloured liquid thus distilled is rectified, whereby fluids are obtained varying in sp. gr. the highest of which is about .670. At each rectification the colour of the liquid becomes more bright and transparent, until at the sp. gr. of about .680, it is colourless and highly volatile. In the process of rectification for the purpose of obtaining a larger product of the oil colourless, about $\frac{1}{3}$ of

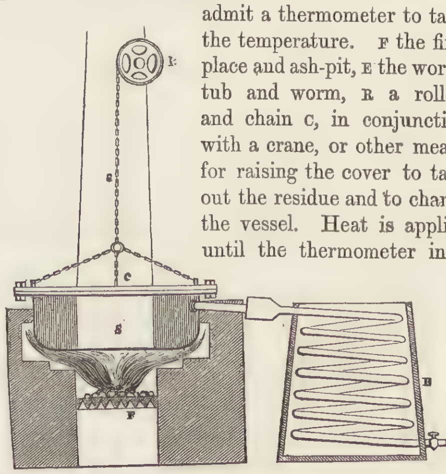


Fig. 437.

water is put into the still. In every state the liquid is a solvent of caoutchouc and several resinous and oleaginous substances, and also of other substances, such as copal in combination with very strong alcohol. The dirt which adheres to the bottom of the still is with difficulty removed: but the inventor adopted the ingenious contrivance of throwing into the still a solder of lead and tin to the depth of about half an inch, and as this became fused, the dirt on its surface was easily removed. The smell of the liquid thus obtained by distillation can be removed by mixing and shaking up the liquid with nitro-muriatic acid or chlorine, in the proportion of a quarter of a pint of the acid to a gallon of the liquid.

Cordage steeped in caoutchisine was found to be remarkably supple and tenacious: water-proof cloth was also prepared by its means, as also some excellent varnishes. The residue left in the still was also found well adapted to the formation of pitch or tar, for the use of the ship-builder. Unfortunately, the high price of caoutchouc has imposed a limit on the general application of caoutchisine, and the other hydrocarbons obtained by the distillation of india-rubber. We therefore return to the more ordinary uses of caoutchouc.

Caoutchouc was not known in Europe until the commencement of the last century, and it continued for a long time in comparative obscurity.[1] It was first used for rubbing out the marks of black-lead pencils. Its use was then extended to the preparation of certain varnishes, which it rendered capable of resisting changes of temperature without cracking and scaling off. The facility with which two recently cut and perfectly clean surfaces of caoutchouc weld together, led to its use in the laboratory for the formation of short elastic tubes, which are used as connectors for a variety of apparatus, in which separate pieces of glass tubing are thus joined together with flexible joints: they are prepared by wrapping a piece of sheet caoutchouc loosely over a glass tube or rod, and then cutting off the superfluous portion with a pair of scissors, Fig. 438: on pressing the fresh cut edges together, they cohere so as to form a perfect tube.

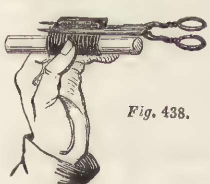


Fig. 438.

Caoutchouc is also used in the preparation of certain surgical instruments, which are required to be both supple and flexible. But the most important application of caoutchouc has been in waterproofing. In fact, caoutchouc is, as M. Dumas remarks, a very wonderful substance. None of the ordinary acid or alkaline caustics attack it: it may be bent in all directions and stretched to a remarkable extent, and returns to its primitive form when the bending or stretching force is removed, and it accommodates itself to all the variations of the surfaces to which it is applied. It may be cut into thin sheets and subdivided into threads and elastic bands: its elasticity can be taken away and restored again at pleasure: it can be cut and moulded in a thousand different manners, according to the caprices of fashion or the devices of invention: there is no waste, for all the shreds and fragments can be cemented together and used as effectually as a new piece.

In the preparation of water-proof clothing there is, however, a defect. The caoutchouc by its solution in some of the essential oils is somewhat modified in character. It retains a portion of the oil, which softens it, and also imparts a certain odour. The problem which has yet to be solved, is how to render caoutchouc fluid, not by the use of oils, which cannot afterwards be entirely got rid of, but by restoring it to that emulsive state in which it flows from the trees which supply it. M. Dumas suggests that the sap itself should be imported in bottles or close vessels, absolutely air-tight, and in this state be prepared for the manufacture of water-proof garments. Or a solution in ether being made of the caoutchouc, the pure caoutchouc precipitated by alcohol should be spread over a piece of cloth properly stretched. A second piece of cloth should then be rolled over this with very strong pressure, and the result would doubtless be a perfectly waterproof cloth without any odour. Or the two pieces of cloth to be cemented together might be wound upon rollers moving together as closely as possible, and one of them heated to a certain temperature. The etherial solution of caoutchouc being allowed to fall upon the heated roller, the ether in evaporating would leave a thin layer of caoutchouc, which would be immediately covered over by the motion of the rollers. If this operation were conducted in a small close chamber, the vapour of ether might be conveyed away to act upon the india-rubber in process of solution. The loss of ether would thus be diminished. We fear, however, that the high price of alcohol, and consequently of ether, in this country, would preclude the adoption of either of these suggestions.

The ordinary method of making waterproof cloth is exceedingly simple. The caoutchouc is dissolved in the oil distilled from gas-tar, and spread upon the surface of a piece of cloth, upon which a similar piece is then extended. Both pieces are then passed between a couple of rollers. Hence the waterproof fabric consists of two pieces of cloth united by an interposed layer of caoutchouc. This cloth is so impervious to moisture that floating or hydrostatic beds are formed of it, and beds and cushions are rendered elastic by inflating them. This method of forming waterproof cloth was invented by Mr. Mackintosh of Glasgow, whose name has become so familiar by being applied to the articles formed of this fabric. One of the greatest objections to articles of this clothing arises from the very perfection of the protection

(1) Few persons are probably aware of the comparatively late introduction of india-rubber into this country. Dr. Priestley in the preface of his work of Perspective, printed in 1770, says:—"Since this work was printed off, I have seen a substance [no name is given to it] excellently adapted to the purpose of wiping from paper the marks of a black-lead pencil. It must, therefore, be of singular use to those who practice drawing. It is sold by Mr. Nairne, Mathematical Instrument Maker, opposite the Royal Exchange. He sells a cubical piece of about half an inch for three shillings; and he says it will last several years."

against moisture which they afford. For as they allow no wet to pass through, they do not allow the insensible perspiration of the skin to pass out. Hence they become inconveniently warm to the wearer, and are doubtless injurious to health. In water-beds the absence of the necessary porosity of a common bed is strikingly shown by the condensation of the perspiration forming streams of water, which wet the bedclothes, and render the bed very uncomfortable.

Caoutchouc has been spread out into sheets by soaking a bottle of india-rubber as imported until quite soft. It may then be inflated by blowing into it until it has become so thin as to be transparent and sufficiently light to ascend when filled with hydrogen gas. If dried in this state it will not again contract, and thin sheets may thus be formed.

In the various fabrics which have been manufactured with caoutchouc as one of the constituents, the warp or longitudinal threads are of caoutchouc, and the weft or cross threads of cotton, silk, or linen, according to the object of the fabric. Elastic braid is made by a machine by covering a thread of caoutchouc with silk or other threads. The threads of caoutchouc are produced by cutting it by means of a machine with the greatest evenness and equality. One pound will make a thread (No. 5) 8,000 yards in length; but this thread may by the machine be again cut longitudinally into 4, making in the whole 32,000 yards from one pound of caoutchouc, and such is the facility obtained by the machinery that two girls are capable of cutting 30 lbs. per day, producing 240,000 yards of No. 5 thread. In working threads of caoutchouc it is found that if they be kept stretched for some length of time, and are exposed to cold, they become set to the length to which they have been stretched, and will no longer have elasticity. Consequently in weaving fabrics with warp threads of caoutchouc, the fabrics when first woven are not elastic, nor can they be extended to a greater length; but in order to impart elasticity to such fabrics, a hot iron is passed over them, whereby the warp threads of caoutchouc shrink back to their original length, and then become elastic. In some instances where the elastic fabric would be liable to be extended beyond the ultimate power of the elasticity of the caoutchouc, instead of having all the warp threads of elastic gum, alternate threads of cotton, silk, or linen are placed in the loom; by this means the fabric cannot be stretched beyond the ultimate power of elastic elongation of the caoutchouc, as the strain would then come on the warp threads of cotton, silk, or linen, and prevent the fabric being further stretched. Dr. Ure states that each thread is rendered inelastic while it is being reeled, by the tenter boy or girl pressing it between his moist thumb and finger, so as to stretch it to at least eight times its natural length, while it is drawn rapidly through between them by the rotation of the power-driven reel. This extension is accompanied with condensation of the caoutchouc, and with very considerable disengagement of heat. The reels, after being filled with the thread, are set aside for some days. The caoutchouc thread of the Joint Stock Caoutchouc Company is numbered from 1 to 8. No. 1 is the finest, and has about 5,000 yards in a pound weight; No. 4 has 2,000 in the pound weight; and No. 8, 700, this being a very powerful thread. The finest is used for the finer elastic tissues, as for ladies' silver and gold elastic bracelets and bands. The ropes made with the strongest of the above threads, covered with hemp, and their elasticity restored by heat, possess extraordinary strength and elasticity.

Numerous patents have been taken out from time to time for improvements in the manufacture of caoutchouc. Among others we may notice Mr. C. Nickel's patent, granted in October, 1836, and which, we believe, includes Mr. Sievier's process. The caoutchouc is first cut into small portions, and well washed in hot water to remove any dirt or impurities, and the cuttings are then dried at about 200° in iron or other vessels heated by steam. The cuttings thus cleaned and dried are next passed through a pair of iron rollers, by which they are blended and pressed together. The caoutchouc is then put into a mill consisting of a roller covered with spikes moving within a hollow spiked cylinder, and ground until it becomes equally and uniformly mixed. During the grinding, great heat is disengaged; and although the water be let in cold, it soon becomes boiling hot, and emits copious vapours. When no water is admitted, the temperature rises much higher, so that the elastic mass of india-rubber, although a bad conductor of heat, cannot be safely touched by the hand. During this grinding, a quantity of muddy water runs off through apertures in the bottom of the drum. In the course of half an hour, the pieces become agglutinated into a soft elastic ball, of a reddish brown colour. This ball is removed to another drum, furnished with spikes or cutting chisels. Here the caoutchouc is kneaded dry, with a little quicklime. It now gets very hot, discharges in steam the moisture imbibed in the previous operation, becomes more compact, and deepens in colour. Dr. Ure, who inspected the process at the establishment of the Joint Stock Caoutchouc Company, at Tottenham,[1] says, that during this second grinding frequent explosions take place, from the expansion and sudden extrication of the imprisoned air and steam. From this second set of drums the ball is transferred to a third set, where it is condensed into a homogeneous solid. Seven of these finished balls, weighing 5lbs. each, are introduced into a larger drum, the shaft of which is studded with blunt chisels. There the separate balls are incorporated into one mass, free from cells or pores, and now fit to be squeezed into a rectangular or cylindrical mould, previously rubbed over with soap-water to prevent adhesion: here it is condensed into a solid block by the compressing action of a screw; but by Mr. Hancock's process this is done by inserting into the cylinder the piston or

(1) "Supplement to Dr. Ure's Dictionary of Arts, Manufactures, &c." London. 1846.

plunger of a hydrostatic press. When the pressing is complete, the caoutchouc is left in the mould till it is cold, but still under pressure; it is then forced out of the mould. If it be desired to cut this block into sheets, it is raised out of the mould *m* very

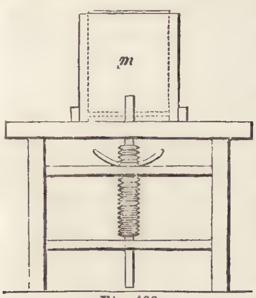


Fig. 439.

gradually by means of a screw, Fig. 439, which being turned, raises the proper quantity, which is ascertained by having a gauge of the thickness required, and when so much is forced beyond the end of the mould, that portion is cut off with a knife, a continuous stream of water being supplied to the knife or cutting edge to keep it cool. A hollow cylinder of caoutchouc may be formed by placing a solid core within the mould, and using a hollow piston or plunger, as in Fig. 440. Cylinders

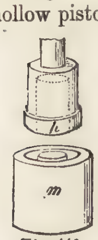


Fig. 440.

of ground caoutchouc may also be formed by means of pressing-rollers with equal and smooth surfaces. The ground caoutchouc directly from the mill is placed between the rollers, which by their revolution pass a continuous thin sheet through them. This is tightly wound upon a wooden roller as fast as the sheet is formed, by which means any degree of thickness may be obtained, and as the same is warm by passing between the rollers, the folds will cohere and become of one close substance.

In order to form the caoutchouc into threads, the hollow cylinder is first cut up into tapes by cutting

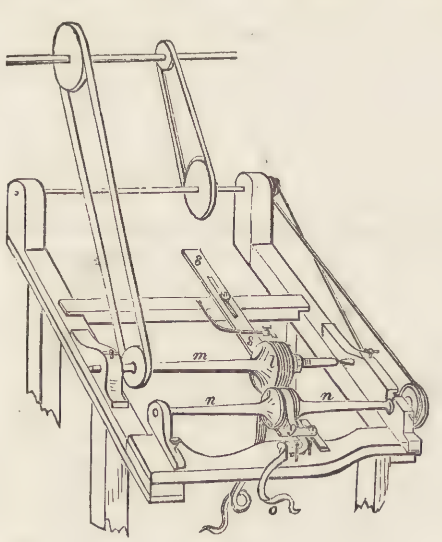


Fig. 441.

it from end to end in a spiral direction. The circular slices or discs may be cut into tapes in a somewhat similar manner, proceeding from the circumference to the centre, spirally. The tapes thus formed are cut into threads by means of the machine, Fig. 441, in which a series of circular knives *l* are fixed on an axis *m*, between two circular plates, one of which is capable of movement, and of being tightly fixed on the axis when the knives are in their places, there being a washer or disc of metal between every two knives for regulating the distance apart, according to the thickness of the thread required. The circular knives are 3 inches in diameter, and are made to revolve with considerable velocity; *n* is another axis, bearing a cylindrical block of hard wood, (such as wainscot oak,) against which the cutting edges of the knives come, and slightly cut into the block, which should be made of several parts or sections in order that the grain may run from the centre outwards in all directions. The axis *n* revolves but slowly in comparison with the cutters, as will be seen by the dimensions of the driving pulleys to each: the axis *m* making about 1,400 revolutions per minute, and the axis *n* only 24: *o* is a tape or sheet of caoutchouc being cut; it is guided between the pins *p*, and between the spring-guide plates *q*, there being a constant stream of water supplied to and amongst the knives by the pipe *r*. *s* is a piece of wood, in the cuts of which the knives work, and are thus cleaned, and any portions of caoutchouc which might otherwise remain between the knives are removed.

Fig. 442 shows another arrangement for cutting a series of threads at one time. It consists of a number of discs of equal thickness, and of the thickness of the intended thread. They are fixed on two shafts or axes, which are geared together by cog-wheels, and between each pair of discs

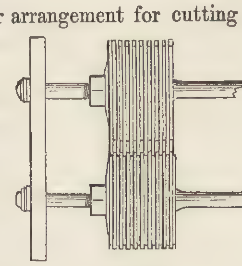


Fig. 442.

is placed a washer of the thickness of the intended thread. The upper and lower discs are so affixed on their respective shafts that they act between each other, and the sheet or tape of caoutchouc is conducted between the two sets of cutting discs. In other respects the arrangements are similar to those of Fig. 441.

We may also notice some of the features of Mr. Walter Hancock's patent (sealed 9th November, 1843). In order to expose a larger surface to the action of the solvent, the india-rubber is cut into shreds by passing it between toothed rollers *a a*, Fig. 443, between which is a bar *b*, so that the rollers have the effect of shears in passing against the bar. The shreds thus produced are in some cases freed from impurities before applying the solvent, by washing them thoroughly. This greatly facilitates the manufacture

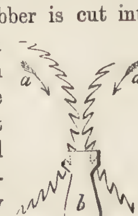


Fig. 443.

of what is called *block-rubber* or caoutchouc, mechanically formed into large blocks for the purpose of cutting into small blocks or sheets.

Fig. 444 is a machine for flatting out the caout-

chouc mixture upon fabrics. It consists of a frame supporting a pair of rollers, *r r; b* is a hopper, into which the material to be flatted into sheets is placed, and which is pressed down upon or between the rollers *r r* by means of a weight. The caoutchouc being dissolved is mixed with cork dust: *r r* are two outer rollers, upon each of which a length of cloth is wound, when the composition of cork and caoutchouc is to be placed between two fabrics. Motion being given to these rollers, the ends of the two separate lengths of cloth are brought from the outer rollers between the rollers *r r*, and secured around the drum D by one or more turns upon it, or by tacking them on. Motion being then given to the drum D, the cloth, with the compound delivered from the rollers *r r*, is wound upon it until the whole lengths of cloth are wound off the outer rollers on to the drum, from which it is removed to be dried. The thickness of the sheets of compound may be varied by adjusting-screws applied to the spindles of the rollers *r r*. When a very adhesive connexion with the cloth or fabric is desired, the cloth may be first covered with a thin coat of solution of caoutchouc, before the composition is milled or pressed between them. The surfaces may be ornamented by embossing them by means of pressure between plates, on which the desired pattern or design is engraved, or by passing them between embossing rollers. These surfaces may also be coloured by mixing any suitable pigment with a thin solution of caoutchouc, laying it on either before or after the surfaces are embossed. A piled surface may also be produced by using appropriate rollers, and for a very compact combination, the rollers may be raised to a blood heat. Small particles of leather or wood may be used with or instead of the cork dust.

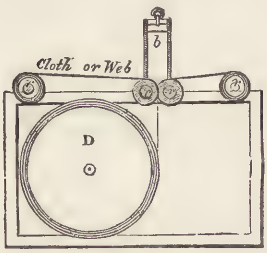


Fig. 444.

Mr. Hancock obtains a solution of india-rubber in ether, turpentine, coal-tar, oil, naphtha, or any other solvent, by introducing the solvent, in a state of vapour, into a vessel containing the India-rubber in small fragments: the vessel is exhausted of air, and kept at the desired temperature by means of a steam jacket.

The following description of the manufacture of waterproof double fabrics is from Dr. Ure's Supplement:—

"The wooden framework of the gallery in which the waterproof cloth is manufactured should be at least 50 yards long, to give ample room for extending, airing, and drying the pieces: it should be 2 yards wide, and not less than 5 high. It is formed of upright standards of wood, bound with 3 or 4 horizontal rails at the sides and the ends. At the end of the gallery where the varnish is applied, the web which is to be smeared must be wound upon a beam resembling in size and situation the cloth beam of the weaver's loom. The piece is thence drawn up, and stretched in a horizontal direction over a bar, like the breast-beam of a loom, whence it is extended in a somewhat slanting direction downwards, and passed over the edge of a horizontal bar. Above this bar, and parallel to it, a steel-armed edge of wood is adjusted, so closely as to leave but a narrow slit for the passage of the varnish and the cloth. This horizontal slit may be widened or narrowed at pleasure by thumb-screws, which lower or raise the movable upper board. The caoutchouc paste being plastered thickly with a long spatula of wood upon the down-sloped part of the web, which lies between the breast-beam and the above-described slit, the cloth is then drawn through the slit by means of cords in a horizontal direction along the lowest rails of the gallery, whereby it gets uniformly besmeared. As soon as the whole web, consisting of about 40 yards, is thus coated with the viscid varnish, it is extended horizontally upon rollers in the upper part of the gallery, and left for a day or two to dry. A second and third coat are then applied in succession. Two such webs or pieces are next cemented face to face, by passing them, at the instant of their being brought into contact, between a pair of wooden rollers, care being taken by the operator to prevent the formation of any creases or twisting of the twofold web. The under one of the two pieces, being intended for the lining, should be a couple of inches broader than the upper one, to insure the uniform covering of the latter, which is destined to form the outside of the garment. The double cloth is finally suspended in a well ventilated stove-room, till it becomes dry and nearly free from smell. The parings cut from the broader edges of the under piece are reserved for cementing the seams of cloaks and other articles of dress. The tape-like shreds of the double cloth are in great request among gardeners for nailing up the twigs of wall-shrubs."

Among other remarkable applications of caoutchouc, in combination with other materials, may be mentioned the paving of stables, lobbies, and halls with blocks of this substance. Some of the stables at Woolwich are thus paved, as are also the Admiralty court-yard, and the carriage-entrance court at Windsor Castle. Boats of india-rubber and cork have been proposed, such as shall be too light to sink, and too elastic to be broken to pieces. It has also been proposed to line ships of war with india-rubber, to prevent accidents from gun-shot splinters, and also to use this substance for hammock-nettings and bulwarks.

The combination of caoutchouc with sulphur produces what is called *vulcanized india-rubber*. The process of *conversion* consists in submitting india-rubber to the action of bisulphuret of carbon, mixed with chloride of sulphur. The caoutchouc cannot, however, be penetrated by this process to any depth, and therefore it is inapplicable when the mass to be acted on is thick. The process of *vulcanization*, invented by Mr. Hancock, is therefore adopted. When caoutchouc is immersed in a bath of fused sulphur, and heated to various temperatures, it absorbs the

sulphur, assumes a carbonized appearance, and lastly acquires the consistency of horn. In the course of these changes, it attains the state of vulcanization which fits it for use. The same vulcanized condition can, however, be produced either by kneading the india-rubber with sulphur, and then exposing it to a temperature of 190°, or by dissolving the india-rubber in any known solvent, as turpentine, previously charged with sulphur. The effects of this treatment are—1st. the india-rubber remains elastic at all temperatures, while in its ordinary state it is quite rigid at a temperature of 40°; 2d, vulcanized caoutchouc is not affected by any known solvents, as bisulphuret of carbon, naphtha, or turpentine; 3d, it is not affected by heat short of the vulcanizing point; 4th, it acquires extraordinary powers of resisting compression. Thus, a cannon-ball was broken to pieces by being driven through a mass of vulcanized caoutchouc; the caoutchouc itself exhibiting no other trace of its passage than a scarcely perceptible rent. The applications of this substance are very numerous. The most familiar example is in the elastic rings and bands now so common. The same substance, adjusted in size and strength to the purpose required, furnishes springs for locks and for the racks of window-blinds. It is also capable of being moulded into the most intricate ornaments; its characteristic elasticity removing all embarrassment in relieving the undercut parts. It furnishes impervious bottles for volatile substances like ether, as well as an excellent inkstand. It is adapted to protect from corrosion wires subjected to the action of the sea, as in the case of the wires required for the electric communication between England and France. For the same reason, air-tubes of vulcanized rubber are better suited for life-boats than those made of canvass, which are liable to be destroyed by the action of the water. A similar tube has been used with success as a substitute for an iron band as the tire of a carriage-wheel, forming, in fact, a noiseless wheel instead of a noiseless pavement, such as wood. A vehicle so arranged is said to run easier than on the present plan. Library chairs on an uncarpeted room may be made noiseless by attaching discs of vulcanized rubber to the bottoms of the legs, and slamming doors may be rendered much less noisy by attaching strips of the rubber to the parts where the door and the door-sill meet. Both these plans have been recently adopted in the reading-room of the British Museum, much to the comfort of the students. Vulcanized rubber has been applied with success in the construction of railroads and railroad carriages. In the former it is laid between the rail and the sleeper, and thus prevents the rails from indicating any traces of pressure; and the springs connected with the buffers of the latter, when formed of this substance, can neither be broken, nor can their elasticity be surmounted, by any degree of concussive violence. In a lecture on this substance, delivered at the Royal Institution in April, 1847, the lecturer, Mr. Brockedon, exhibited objects illustrative of the great physical change induced on caoutchouc by vulcanization. He showed a screw with its recipient, both made of this substance, as well as a form of letter-press, (like a stereotype page,) for printing. He also noticed its usefulness in making epithems for surgical purposes, gloves and boots for gouty persons, &c.

CAPERS, the unexpanded flower-buds of the caper-tree, (*Capparis spinosa,*) a trailing shrub, growing in Italy and the south of France. Preserved in vinegar, these flower-buds constitute a well-known article of commerce, and of luxury at our tables. The cultivation of the tree for this purpose is confined to a comparatively narrow district in the south of France, namely, Cuges and Roquevaire, in the department of the Bouches-du-Rhône, and Olioulles, in the department of Du Var. The gathering time is from June to August. As soon as the morning dew is off the trees, women wearing a sort of flexible basket at their waists, collect the buds, at the rate of twenty-five or thirty pounds' weight in a day. The plantations are divided into compartments, each of which is visited every week during the season; an experienced picker being able to tell the precise day when the buds will be in the best condition. A small and choice form of bud is called the *nonpareil;* but if this be neglected for one day, it becomes a second-rate bud, called *capucine;* if not gathered then, it becomes on the third day a *capote.* These three qualities are perfectly well known to merchants, and are more esteemed than buds gathered at random. But the less scrupulous cultivators are not only careless in this respect, but often allow the flower to ripen its fruit, which is a kidney-shaped seed, and which is sold with the commoner sorts of capers. An inferior sort of caper is sold as *flat capers.*

In some cases, capers are exposed to the air before pickling; but the best way is to plunge them in vinegar at once, change the vinegar in a week's time, and then fasten up the cask, and keep it undisturbed until the sale. The finest vinegar should alone be used.

The caper sales take place about the month of September, and on the day fixed for the delivery of the capers, the vinegar is drawn off, and they are set in baskets to drain. They are then weighed, and delivered to the merchant, who usually takes them away in large casks, into which he returns the vinegar in which the capers have been preserved, which is ceded to him as a sort of perquisite when the sale is completed. Capers are exported to most parts of Europe. Our own consumption is not very large. In 1840, it amounted to 84,000 lbs. weight, and part of this amount was from Sicily.

CAPILLARY ATTRACTION. If the extremities of tubes of very fine bore be immersed in water, the water will ascend in them to a certain height, which is great in proportion to the narrowness of the bore of the tube. Such tubes are called *capillary,* from their bore being not much thicker than a *hair,* and this form of adhesion is therefore called *capillary attraction.* The surface of the little column thus suspended will be a hollow hemisphere as at *a*, Fig. 445. If the same tube be plunged into mercury,

the liquid instead of rising above, will be depressed below the general surface as shown in *b*, Fig. 446, and the surface of the mercury will be convex instead of concave. This effect will also be produced in capillary tubes plunged in water, provided the water cannot wet the tubes, as when they are covered with a thin film of oil, which prevents the adhesion.

"The phenomena of capillary attraction and repulsion, may also be seen in vessels containing fluids. If the fluid be capable of wetting the sides of the vessel which contains it, it will be raised and become concave all round the sides, as may be seen in a glass of wine or a cup of tea, and as shown in Fig. 445, *a;* but if the glass or cup be too full, the absence of lateral attraction by the vessel, and the predominance of the force of cohesion from within, will give the liquid a rounded form. If the vessel cannot be wetted by the fluid, as when it is greasy, or mercury be used, the fluid will be depressed all round the vessel and have a convex surface, as in Fig. 446.

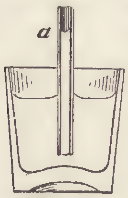


Fig. 445.

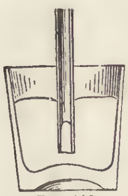


Fig. 446.

Some curious appearances of attraction and repulsion are produced by the operation of *capillarity* (under which term all effects depending on the adhesion of fluids to solids are now included). Two balls of pith or wood, either both dry or both wet, floating in water, attract each other as they do in all cases when so distant that it matters not whether the surface be raised or depressed where it approaches them; but if one ball be wet and the other dry, they repel each other as soon as the liquid surface which separates them is covered. All these effects have been made the subjects of deductive science and with great success. They have been generalized by Clairaut into the following law:—If the *intensity* of the attraction of the solid on the fluid be *greater* than *half* that of the fluid on itself, the fluid will *elevate* itself above the solid; if it be *less*, it will *depress* itself; and if it be *equal*, it will neither elevate nor depress itself." [1]

Examples of capillary attraction are very numerous; such as the ascent of water in a piece of lump-sugar, or in a sponge, the pores of the sugar or of the sponge acting as capillary tubes; the ascent of oil in a lamp and tallow in a candle, the cotton fibres of the wick serving also as fine tubes. The facility with which water becomes diffused among sand is also due to this cause. Sap ascends in plants by the same force, and some idea of its intensity may be gained by fitting a dry plug of wood tightly into a stout tube of glass or porcelain. If a projecting portion of the wood be allowed just to dip into the water, the liquid will ascend and cause the wood to swell with such force as to burst the tube, although capable of resisting a pressure of more than 700lbs. on the square inch. Advantage is taken of this property in the formation of millstones. A mass of stone is cut into a cylinder several feet high, which is subdivided into horizontal pieces, so as to make as many millstones, by chiselling out horizontal grooves quite round the cylinder, at distances corresponding to the thicknesses intended to be given to the millstones: wedges of wood are driven into this groove: these are then wetted, and the next morning the different pieces are found separated from each other by the expansion of the wood, consequent on its absorption of moisture, "an irresistible natural power," as Sir John Herschel remarks, "thus accomplishing almost without any trouble and at no expense, an operation which, from the peculiar hardness and texture of the stone, would otherwise be impracticable but by the most powerful machinery or the most persevering labour."

An interesting class of phenomena has been discovered by M. Dutrochet, which have a great analogy with those of capillarity. When two different liquids are separated by a porous partition, such as an animal or vegetable membrane, a motion is induced through the pores of the membrane of one liquid towards the other: this is termed *endosmose*, or "current towards the interior." Thus, if a vessel be divided into two distinct parts by means of a membrane, and water be poured into one part and a solution of gum in water, or acetic or nitric or muriatic acid, into the other, there will be endosmose from the water to the solution of gum, and to the acids respectively. There is no endosmose from one portion of liquid to another portion of the same kind of liquid, nor from water to a dilute solution of sulphuric acid. Sugar in solution of the same density with solution of gum gives a double elevation of the gum. Of all vegetable substances sugar exhibits the strongest force of endosmose, as does albumen among animal substances. The term *exosmose* is applied to phenomena the reverse of endosmose: it is due to the same cause, but has another direction.

Some very striking effects of endosmose and exosmose may be exhibited with some of the gases. For example; confine a portion of common air in a tumbler or wide-mouthed jar by carefully tying over it a piece of thin sheet india-rubber, and place it under a large bell glass filled with hydrogen and standing in a dish of water: the hydrogen will gradually find its way through the india-rubber and act upon it with such elastic force as to distend it and ultimately to burst it. If the included jar contain hydrogen, and the bell-glass, air, an opposite result will be obtained; the india-rubber will become concave instead of convex. This subject, however, is not of a sufficiently practical nature to be further noticed in a work of this kind.

CAPS. [See PERCUSSION CAPS.]

CAPSTAN, (French *cabestan,*) a vertical WINDLASS employed on board large vessels in the operation of weighing anchor, and for otherwise assisting the mechanical power of the crew. It consists of a drum or barrel revolving on a verticle spindle, with holes cut in the upper part or drum head for the

(1) Tomlinson's Introduction to the Study of Natural Philosophy, published in Weale's Rudimentary Series, 1848.

reception of horizontal levers or *capstan bars* used for turning it round. The cable, or in large ships a smaller rope attached to the cable, called the *messenger*, is wound two or three times round the barrel, and as the capstan is turned round by men at the capstan bars, another set of men take in the

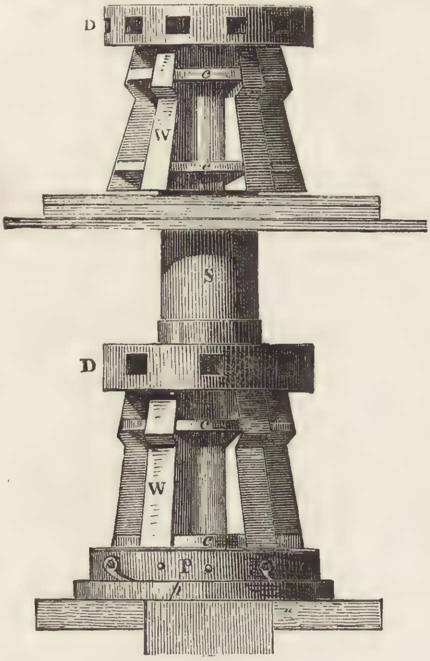


Fig. 447.

slack of the cable or messenger as it unwinds from the barrel. This machine was introduced into England in the reign of Elizabeth, and was probably obtained through the French from the Spaniards or Portuguese, who, from the use of the word *cabestante* in the second voyage of Columbus, appear to have been acquainted with it at least as early as the latter part of the 15th century. The machine has passed through a succession of improvements which need not be noticed here. The common capstan Fig. 447, consists of the *spindle* S, the *drum-heads* D, the *whelps* W, of which *c c* are the *cheeks*, P is the *paul-head* and *p* the *paul-rim*. The *barrel* of the capstan is covered by the whelps, of which there are six to each capstan, and is made parallel from end to end: the whelps are bolted to the barrel, and the drum-head is screwed down about an inch upon the whelps. The woodwork is made of well-seasoned English oak: the bars are usually of ash and about 10 feet long: they are inserted into holes mortised in the drum-head, 12 in the upper and 6 in the lower capstan, and they are secured by pins to prevent them from flying out by any recoil of the capstan; an accident which is guarded against by the use of pauls, of which there are two kinds; one bolted to the partners P′, that turn horizontally and are moved by hand: the other fastened to the paul-head and falling alternately into small iron cells in the paul-rim, and so disposed that the capstan cannot recoil above half the length of one of the cells without being checked by the pauls. The capstan is often made to consist of two parts attached one above the other to the same vertical axle, one being on the quarter-deck, and the other on the main-deck of a ship, both parts being turned by men who act against the bars of both at the same time. If there is a windlass on board ship, the lower barrel is dispensed with and the spindle is tapered gradually from the partners to the step. Sometimes the spindle is of iron, and runs down no further than the underside of the partners, where it is secured by a forelock.

In Captain Phillips's patent capstan, Fig. 448, W is the exterior wheel, which is fixed and is hung in the fore and aft carriages C C, Figs. 449, 450, to prevent the motion of the ship from disturbing the machinery. B and C are two plates confining the centres of the pinions *p p*: into the top of these plates the bolts P P fall to increase the power; H H are bearings in the spindle, round the two lower of which the main deck capstan plays loosely, and the upper is the bearing in the quarter-deck partners; E is the centre pinion fixed on the spindle corresponding to P, Fig. 449, and *p p* are the pinions that act between W and P. At A, Fig. 450, is a hexagon on the spindle, over which the clutch-box I, Fig. 448, is fitted; K K are levers by which I is raised, to the outer ends of which the chains that carry the bolts P P are fastened, thus bringing into one action the two operations of separating the capstans and fixing the lower one to the machinery. The links O O are made to fasten to the

Fig. 448.

hooks N N in the capstan head, as a method of keeping the clutch-box raised; Q Q are small bolts which can be pushed into the links of the chain M, to prevent, if necessary, the bolts P P from descending: when thus arranged, the capstans become separate and distinct

machines. By raising the levers K K the clutch-box falls, the bolts P P are suspended, and the whole becomes a common double capstan. Should any difficulty occur in raising the anchor, all that is necessary is to press down the levers so far as to hook the chain O, and the power is increased fourfold. "The reason of this is sufficiently obvious; the power applied to the upper capstan acts through the spindle upon the pinion, P, Fig. 449, which communicates its motion to that at p; now as this last turns about the teeth of the fixed wheel, it follows, that whatever force is exerted by P will be doubled at the centre of the pinion p,

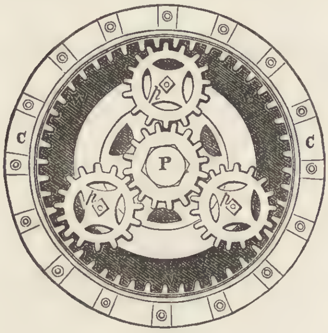


Fig. 449.

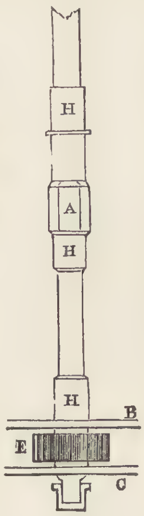


Fig. 450.

that is, will communicate itself with a double force to the lower capstan; and as it is necessary in calculating these effects to consider the power and weight as applied at an equal distance from the centre, we must suppose the power applied to the upper capstan to be half that which acts at the circumference of the centre pinion: that is to say, the power applied to the upper capstan is to that exerted at the lower as 1 to 4."

The capstan is superior to the windlass in point of expedition, because in the latter the levers must be shifted into fresh holes four times in each revolution: a larger number of men can also be employed at the capstan bars than at the handspikes of a windlass: but the men exert their strength more effectually at the windlass than at the capstan, since in the latter case they are employed to draw horizontally, when they exert a force of only about 35 lbs., whereas in the windlass, they apply their own weight at the extremity of the lever, and the average weight of a man is about 150 lbs. or 4 times his power of traction.

CARAT, a bean, the fruit of an Abyssinian tree called *kuara*. It varies very little in weight from the time of its being gathered, and is used as a weight for gold in Africa, and for diamonds in India. The carat consists of 4 nominal grains a little lighter than 4 grains troy. $74\frac{1}{18}$ carat grains are equal to 72 troy grains. The carat is divided into halves, quarters or carat grains, eighth, sixteenth, and thirty-second parts. [See also ASSAYING.]

CARAWAYS, the seeds of *Carum carui*, a plant found in pastures over the whole of Europe, naturalized in England, and largely cultivated in Essex and Suffolk. The seeds, which are the furrowed halves of the ripe fruit, are used in medicine as a carminative, by confectioners and biscuit-bakers, and by the brewers' druggists as a flavouring for beer. It is a biennial plant, and is usually sown with coriander, and sometimes a crop of teazles is raised on the same land. By distillation with water, caraways yield about 5 per cent of a fragrant aromatic essential oil of a pale brown tint which deepens by age. It is a mixture of a hydrocarbon (*Caruine* $= C_{10} H_8$) and of an oxyhydrocarbon, which distilled with phosphoric acid yields a thick oil, (*caruole* or *caracole* $= C_{26} H_{18} O_2$).

CARBON, an elementary substance of first-rate importance in chemistry both organic and inorganic, and also in the Useful Arts. It is very widely diffused throughout the kingdoms of nature, and exists under an immense variety of forms. The purest form of carbon is the *diamond*, which is found throughout the range of the Ghauts in India, but chiefly at Golconda, in Borneo and also in Brazil. All the largest diamonds are from Golconda. The Brazilian mines are said to furnish from 10 to 13 lbs. weight of diamonds every year, of which not more than from 800 to 900 carats are fit for jewellery. It is always associated with materials transported from a distance, such as rolled gravel, so that its origin is doubtful. On removing the crust which covers the crystals, their exceeding brilliancy becomes apparent; they refract light powerfully and are generally perfectly transparent, although diamonds have been found of a black, blue, green, and of a beautiful rose colour. Those which are colourless are most esteemed: those which are slightly brown or tinged only with the other colours are least valuable. Black diamonds are extremely rare. The primitive form of diamond is the regular octahedron, or two four-sided pyramids, of which the faces are equilateral triangles, applied base to base, Fig. 451. It is also found in figures bounded by 48 curved triangular faces, but can always be cleaved in the direction of the faces of the octahedron, which possess that particular brilliancy characteristic of the diamond. The diamond is the hardest of the gems. Its sp. gr. varies from 3.4 to 3.6. It is a non-conductor of electricity; is not acted on by any solvent, nor is it affected by heat only, for it may be heated to whiteness in a covered crucible without injury: it burns in the open air at and about the melting point of silver, charcoal sometimes appearing on its surface, and it is entirely converted into carbonic acid gas. Attempts have been made to fuse or crystallize some pure form of carbon, or in other words to manufacture diamonds, but they have all failed. According to a recent experiment, when exposed to the very high temperature produced by a Bunsen's battery of 100 plates, or by a condensed mixture of carbonic oxide and oxygen gas, the diamond fuses, and is converted into a mass resembling coke: its sp. gr. is thereby reduced from 3.336 to 2.678.

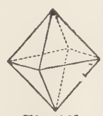


Fig. 451.

The combustibility of the diamond was ascertained by the Tuscan philosophers and the Hon. Mr. Boyle, who, by exposing a diamond in the focus of a large

lens, consumed and dissipated it. It was also burnt by means of melted nitre in a gold tube by Mr. Smithson Tennant, and it was completely volatilized in the brilliant arch of flame evolved between charcoal points in the galvanic battery of the Royal Institution. Lavoisier proved that carbonic acid was evolved as a product in the combustion of the diamond and that of charcoal, a result abundantly confirmed by Messrs. Allen and Pepys and others. Sir George Mackenzie converted iron into steel by means of powdered diamonds instead of powdered charcoal. Mr. S. Tennant having placed a diamond in a gold tube supported in a state of incandescence, a stream of oxygen by means of gentle pressure was made to traverse it, and the result proved that the oxygen was converted into an equal volume of carbonic acid gas, which was found in an opposite receiver resting over mercury. Sir Humphry Davy when at Florence made some experiments with the Grand Duke's burning lens on the combustion of the diamond. 1.84 grains of small diamonds were placed in a platinum capsule, in a glass globe of the capacity of 14.9 cubical inches, and supplied with oxygen gas, Fig. 452. "Soon after the capsule was placed in the focus in bright sunshine, the diamonds burnt with great brilliancy, and continued to burn until they had considerably diminished in bulk; but their splendour of combustion gradually became less, and before they had apparently lost half of their volume, the process ceased. By placing them a second time in the focus, after agitating the globe so as to change their places, the combustion was again produced; but the light was much less vivid than before, and the combustion continued for a much shorter time. They were exposed to the concentrated rays a third and a fourth time, but after the fourth time they seemed incapable of burning." The fragments which remained weighed .52 of a grain; they were not black, but were deprived of lustre. Sir H. Davy also ignited a small diamond weighing .45 of a grain, in a vessel of chlorine gas, and kept it in a state of intense ignition by directing on it the solar focus by means of the great lens of the Florentine Museum for more than half an hour: but the gas suffered no change, and the diamond had undergone no diminution of weight, and was not altered in appearance.

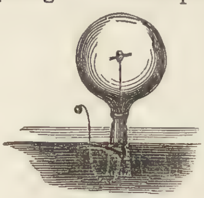


Fig. 452.

The art of cutting and polishing diamonds is supposed to have originated in Asia at some unknown period. It was accidentally discovered in 1456 by Louis Berquen, of Bruges, that by rubbing two diamonds together a new facet was produced. Diamond powder obtained by this rubbing is used for polishing the diamond. For the purposes of jewellery, the diamond is prepared by *splitting*, *cutting*, and *polishing*. The portions not required in shaping the stone are split off by fixing the stone in a ball of cement, about the size of a walnut: the line of division is then drawn a little way with a pointed diamond, fixed in another ball of cement: the stone is then split with the blunted edge of a razor, struck with a hammer. The small fragments removed, when too small for jewellery, are called *bort*. Diamonds are *cut* by the operation of one stone upon another. The stones are cemented in the ends of two sticks, supported on the edges of a small strong mahogany box, Fig. 453, about 4 inches long, 3 inches wide and 3 inches deep. The sides are half an inch in thickness, which gives it considerable strength. The upper surfaces of the four sides of the box are each covered by a rim of steel, and in the centre of each of the longest sides a pin of steel is firmly fixed: these pins are used as fulcra, against which the handles or sticks holding the stones are to be firmly pressed when in operation. The stones are then forcibly rubbed against each other, by which means they abrade each other in nearly flat planes, and remove a fine dust (*diamond powder*), which falls through the fine holes in the bottom of the box, and is there collected. By means of this powder diamonds are *polished*. An iron lap or *skive* being charged with diamond powder, the stone is guided by mechanical means: it is fixed by soft solder in a copper cup or *dop*, attached by a stout copper wire to the end of the *pincers*,—a flat board, terminating at the other extremity in two feet, which rest upon a fixed support; the whole forming a long and very shallow triangular stool, loaded at the end near the stone. The stone is readjusted for producing every separate facet.[1]

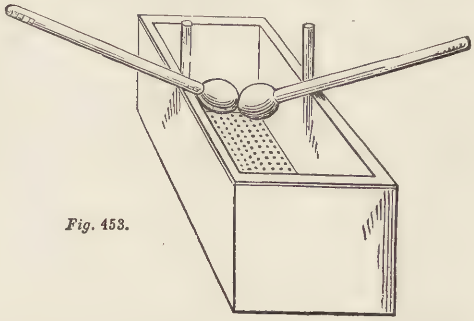


Fig. 453.

Diamonds are cut into various forms, called the *Brilliant*, the *Rose*, and the *Table*. The first form shows the gem to the best advantage, and is always set with the table upwards. In the rose the entire surface is covered with equilateral triangles terminating in a sharp point at the summit. This form is used when the spread of surface is too great for its depth, and it could not be cut into the brilliant form without great loss. The table is applied to such diamonds as may be regarded as plates, laminæ, or slabs, of small depth compared to their superficial extent. The brilliant and the rose lose in cutting and polishing somewhat less than half their weight, so that the value of a cut stone is double that of an uncut one, without reckoning the expense of the process. Small diamonds are sometimes set on black or coloured foil,

(1) This subject will be resumed, if space permit, in the Article LAPIDARY-WORK. In the meantime, the reader interested in the subject may consult Mr. E. Turrell's paper on splitting, cutting, and polishing diamonds, contained in Gill's "Technological Repository." 1827.

but a well-proportioned brilliant of extreme purity is best displayed when entirely exposed. The rose diamond is flat underneath, and its upper surface, raised in the form of a dome, is cut into facets. It has commonly six facets in the centre, triangular in shape, and converging to a point at their summit. The bases of these abut on another range of triangles in a reversed order, their bases being above, and conjoined with the bases of the higher facets, their points forming what are called *feuillets* or leaves. These last triangles have spaces between them, each of which is cut into two facets. The rose diamond is thus cut into 24 facets, and the surface of the gem is divided into two parts, of which the higher part is called the crown, and the lower part the teeth.

That part of the *brilliant* which rises in relief is always thinner than the *rose* diamond, and the entire thickness of the stone is divided into two unequal parts; $\frac{1}{3}$d is reserved for the upper surface of the gem, and $\frac{2}{3}$ds for the lower portion: this part, which is embedded and so far concealed, is called the *culasse.* Jeffries calls the lower flat part the *culet;* the superior one the *table;* the central line of the entire diamond the *girdle,* and the facets *skil* and *steel* facets. In a perfectly formed well-proportioned stone, the lower table should be $\frac{1}{5}$th of the upper table. The table has eight panes, and the circumference is cut into facets called *pavillons.* These should be placed in the same order as the upper facets, so that all false play of light may be avoided. The beauty of the brilliant depends on the sparkling splendour of its light, resulting from the high powers of refraction which distinguish this gem. The *rose* diamond darts a great splendour of light in proportion as it is more spread than the *brilliant.* The latter was an improvement on the *table* diamond introduced in the seventeenth century, and the advantage is caused by the difference in cutting it. It is formed into 32 facets of different figures, and inclined at different angles around the table upon the superior surface of the stone. The culasse is cut into 24 facets round a small table, which converts the culasse into a truncated pyramid. These 24 facets below, as well as the 32 above, are differently inclined, and exhibit different figures. The facets above and below must correspond perfectly, and the proportions be so exact as to multiply their reflections and refractions, so that the prismatic rays may be seen to the best advantage.

Fig. 454, No. 1, represents a regular octahedral diamond; No. 2, the top and bottom reduced, to form the table and collet; No. 3, the same, single-cut. No. 4 is a profile of a full-sized brilliant, in which *a* is the table, *b* the collet, *c* the girdle, *d* the bizet, and *e* the collet side. No. 5 is the table and bizet of No. 4: No. 6 the collet and collet side of the same. (Nos. 1 to 6 represent the sizes of brilliants of from 1 to 6 carats, cut in exact proportion.) No. 7 represents another brilliant. Nos. 11 and 12 are two views of a rose diamond: No. 8 table and bizet; No. 9 collet and collet side. Nos. 11, 12, 8, and 9 represent the size of a well-proportioned 10-carat diamond. Nos. 10 and 15 a table diamond; No. 13 a lasque; No. 14 the same, with one bevel.

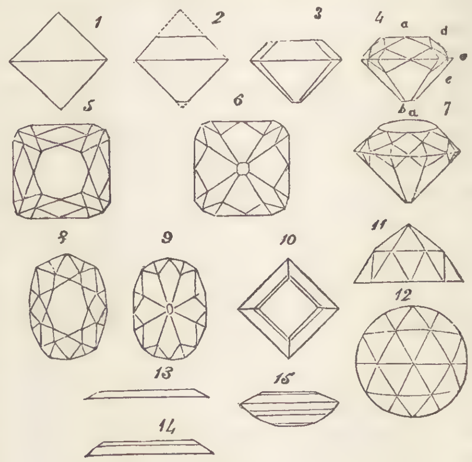


Fig. 454.

A, Fig. 455, is an instrument called by diamond-cutters *the compass.* It is formed of a piece of plain brass for the base, with a movable arm in the centre,

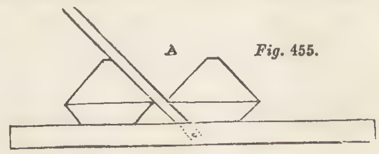


Fig. 455.

which in the figure is at 45°, measuring the inclination of the collet side to the girdle, and of the bizet to the table, at the supplement of the same angle.

The following are copies of some of the largest known diamonds. Fig. 456 is the Pitt or Regent diamond; the dotted line being the outline of the rough gem. This diamond is said to have been found in Malacca: it was purchased by Thomas Pitt, Esq. (grandfather of the first Earl of Chatham) when governor of St. George, in the East Indies,

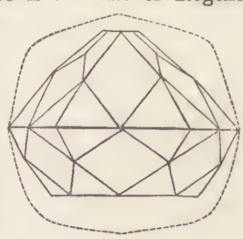


Fig. 456.

in the reign of Queen Anne, for 20,400*l.*; it weighed when raw 410 carats, and when cut 136$\frac{1}{2}$ carats. It was brought to London, cut as a brilliant, and sold to the Duke of Orleans for the king of France, in 1717, for 135,000*l*: 5,000*l.* was spent in the negotiation, &c. The cutting occupied two years, and is said to have cost 3,000*l.*: the fragments were worth several thousands, and the diamond has since been valued at 400,000*l.* Napoleon placed it in the hilt of his sword. It is still preserved among the jewels of France.

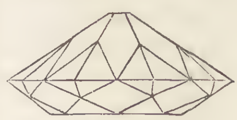


Fig. 457.

The Pigot diamond, Fig. 457, weighs 49 carats, and is valued at 40,000*l.* Some years ago, it was disposed of by lottery, and became the property of a young man who sold it at a low price. It is said to have

been ultimately purchased by the Pacha of Egypt for 30,000*l.*

The Austrian diamond, Fig. 458, weighs above $139\frac{1}{2}$ carats. It belongs to the Emperor of Austria, and was formerly in the possession of the Grand Duke of Tuscany.

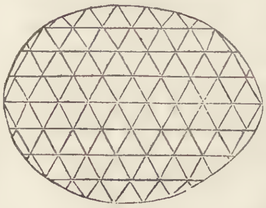


Fig. 458.

The Nassuc diamond weighs 79 carats 2 grains. It was among the spoils taken during the Mahratta war, and is valued at 30,000*l.* It is of great purity, but of bad form.

The grand Russian diamond is said to have been the eye of an Indian idol, and to have been stolen from thence by a French—some say an Irish—soldier, who sold it to the captain of a ship for 2,000*l.*, and the captain disposed of it in Europe for 20,000*l.* At length it fell into the hands of a merchant, who sold it to Prince Orloff for Catherine, Empress of Russia, for 90,000*l.* in cash, an annuity of 4,000*l.*, and a patent of nobility. It weighs scarcely 200 carats.

The Koh-i-noor, or "Mountain of Light," the largest known diamond in the world, excepting the Brazilian stone among the crown jewels of Portugal, has lately been added to the trophies of the British sovereign. It was in the year 1550, before the Mogul dynasty had been established by the prowess of the great Akbar, that this marvellous stone was discovered in the mines of Golconda. It passed in the train of conquest, and as the emblem of dominion, from Golconda to Delhi, from Delhi to Mushed, from Mushed to Cabul, and from Cabul to Lahore. When first given to Shah Jehaun, it was still uncut, weighing, it is said, in the rough state, nearly 800 carats, which were reduced by the unskilfulness of the artist to 279, its present weight. It was cut by Hortensio Borgio, a Venetian, who, instead of receiving any remuneration for his labour, was fined 10,000 rupees by the enraged Mogul. It is rose-cut; and a general idea may be formed of its shape and size by conceiving it to be the pointed half of a small hen's egg; though it is said not to have risen more than half an inch from the gold setting in which it was worn by Runjeet. Its value is scarcely computable; though two millions sterling has been mentioned as a justifiable price, if calculated by the scale employed in the trade.

Small diamonds and fragments made up in small sealed bags are sold in the East by the diamond merchants. According to Jeffries, the value of diamonds is in the duplicate ratio of their weights. Thus, if an uncut diamond of one carat be worth 2*l.*, that of one cut and polished would be valued at 8*l.* sterling in the brilliant. A carat weighs four nominal grains, or 3.166 grains troy. At this rate a cut diamond of two carats would be $2 \times 8 \times 2 = 32$*l.*; one of three, $3 \times 8 \times 3 = 72$*l.*; one of four, $4 \times 8 \times 4 = 128$*l.*; and one of five, $5 \times 8 \times 5 = 200$*l.* The rose diamond is of inferior value, but has been rated at 4*l.* the carat when polished. For the purpose of estimating diamonds of inconsiderable size, the jeweller employs a gauge, in the handle of which are embedded small crystals of various relative sizes, from $\frac{1}{64}$th to $\frac{1}{4}$th of a carat, and a comparison is therewith made when there are numbers of various minute sizes. The rough diamond is called *bort*, and *points* are those small fragments which are set in glaziers' cutting diamonds.[1]

The chief application of the diamond is for ornamental jewellery, but there are other interesting applications of this gem in the useful arts. It has been employed in common with the sapphire and ruby in some descriptions of wire-drawing. Its superiority in this respect over a steel plate depends upon its superior hardness, so that a wire of invariable diameter can always be obtained. The diamond is employed as end pieces in chronometers, to close the socket in which the pivot moves, and against which it abuts. It has been successfully employed for forming small deep lenses for single microscopes, possessing high refractive power with inferior dispersive power, and very little longitudinal aberration. Mr. Pritchard has formed a very thin double convex lens of the diamond of equal radii, and about $\frac{1}{25}$ inch focus, from a very perfect stone of the first water. A diamond and a piece of plate-glass ground in a similar form, and with the same radius, are in their comparative magnifying powers as 8 : 3; so that if the power of the glass lens be 24, that of the diamond would be 64. Mr. Wilson Lowry applied the diamond instead of the steel point in etching on copper; a great improvement, as the steel point soon gives way. For these and similar useful purposes diamond bort is employed; an article of extensive application in the hands of glass-cutters and glaziers, seal-engravers, dentists, copper-plate engravers, lapidaries, china-menders, engravers for calico-printers, hard steel turners, and engravers on that metal in every state of hardness and temper; also for dividing on hard steel and glass for micrometers, &c. Diamond powder is used in conjunction with the ordinary tools of the seal engraver, and also in other arts. No other material has been found adequate to take the place of this costly substance, unless, indeed, Mr. Nasmyth's discovery can be made available. That gentleman found that coke is possessed of one of the most remarkable properties of the diamond, in so far as it has the property of *cutting* glass; not merely *scratching* it, for this property is possessed by all bodies that are harder than glass. The cut produced by coke is a perfect, clear, diamond-like cut, so clean and perfect as to exhibit the most beautiful prismatic colours owing to the perfection of the incision. Coke has hitherto been considered as a soft substance from the ease with which a mass of it can be crushed and pulverised; but it will be found that the minute plate-like crystals of which a mass of coke is composed, are very hard. This dis-

(1) The following treatises have been published on the Diamond:—*Treatise on Diamonds and Pearls*, by David Jeffries, Jeweller. London, 1751. Second Edition. *Treatise on Diamonds and Precious Stones*, by John Mawe. London, 1823. *A Memoir on the Diamond*, by John Murray. London, 1831.

covery is likely to prove of value in many processes in the arts. Messrs. Chance of Birmingham are reported to have stated that in all probability the knowledge of this fact would lead to a saving of nearly 400*l.* a-year in their establishment alone.

The glazier's diamond has been made the subject of investigation by Dr. Wollaston, who draws a clear distinction between *scratching* and *cutting.* "In the former the surface is irregularly torn into a rough furrow; in the latter a smooth fissure or superficial crack is made, which should be continued without interruption from one end to the other of the line in which the glass is intended to be cut. The skilful workman then applies a small force solely at one extremity of this line, and the crack which he forms is led by the fissure almost with certainty to the other." Persons who set diamonds for the use of the glazier always select natural diamonds distinctly crystallized, which they term *sparks.* The reasons why those which are cut by art will not answer the purpose, is thus explained by Dr. Wollaston:—"When a diamond is formed and polished by the lapidary, all the surfaces are *plain* surfaces, as far as it is in his power to make them so, and consequently the edge or line in which they meet is straight. But in the natural diamond there is this peculiarity in those modifications of its crystals that are chosen for this purpose, that the surfaces are in general all *curved,* and consequently the meeting of any two of them presents a curvilinear edge. If the diamond be so placed, that the line of the intended cut is a tangent to this edge near to its extremity, and if the two surfaces of the diamond laterally adjacent be equally inclined to the surface of the glass, then the conditions necessary for effecting the cut are complied with. The curvature however of the edge is not considerable, and consequently the limits of inclination are very confined; for if the handle be either too much or too little elevated, then one or other extremity of the curve will be made to bear angularly upon the glass, and will plough a ragged groove by pressure of its point. But on the contrary, when the contact is duly formed, a simple fissure is effected as if by lateral pressure of the adjacent surfaces of the diamond directed equally to each side. By that means, adjacent portions at the surface of the glass are forced asunder farther than the mere elasticity of the parts beneath will allow, and a partial separation or superficial crack is produced. The effects of inequality in the lateral inclination of the faces of the diamond to the surface of the glass are different, according to the degree of inequality. If the difference be very small, the cut may still be clean; but as the fissure is then not at right angles to the surface, the subsequent fracture is found inclined accordingly. But when an attempt is made to cut with an inclination that deviates still more from the perpendicular, the glass is found superficially flawed out on that side to which the greater pressure was directed, and the cut completely fails." The depth to which the fissure made by the diamond penetrates need not be greater than $\frac{1}{200}$th of an inch. As the form of the cutting edge appeared to be the chief circumstance on which the property of cutting depends, Dr. Wollaston succeeded in giving this form to other hard stones, such as sapphire, ruby, spinell ruby, rock crystal, &c., each of which had the power of cutting glass for a short time with a clear fissure. Although the ruby is very hard, yet the edge thus produced was not durable, arising probably from "the grain or position of its laminæ having been unluckily oblique. And it seems highly probable that the singular durability of the edge of the cutting diamond is owing in some measure to this circumstance, that its hardness in the direction of the natural angle of its crystal, is greater than in any other direction, as we find to be the case in other crystals of which the various degrees of hardness in different directions can be more easily examined."[1]

Dr. Wollaston's remarks on the superior hardness of the external laminæ or skin of the diamond in its natural crystallized state are borne out by experience. Diamond-cutters are so well aware of this that they never begin to polish a diamond, however favourable the plane of a crystal may be, without abrading that plane against another diamond, in order to remove the external surface. It is this extreme degree of hardness that makes the natural diamond so peculiarly fit for cutting glass, and also for indenting extremely fine lines on the surface of glass where microscopic divisions are required.

Mr. Turrell remarks that in all cases the diamond that cuts glass most successfully has the cutting edges of the crystal placed exactly at right angles to each other, and passing exactly through a point of intersection made by the crossing of the edges. In this case it appears to be that portion of one of the edges which is very near the point of intersection that cuts, and scarcely any other. Figs. 459, 460, are an

Fig. 459.

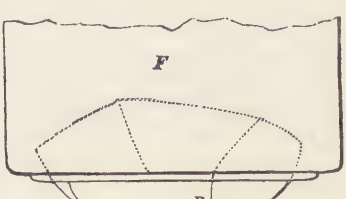


Fig. 460.

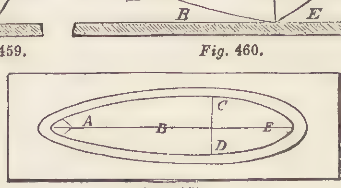


Fig. 461.

end and side elevation, and Fig. 461 a plan, of a diamond, drawn on a large scale. A B represents the leading curved part of the cutting edge, and D, Fig. 460, and C D, the line of intersection, crossing the line A B at right angles; E being the following part of the cutting edge. The general figure of the stone is indicated in all the figures by the dotted lines; and

(1) Philosophical Transactions for 1816.

its position in a hole formed in the metal block F, in which it is first adjusted and afterwards secured by hard solder, is also shown.

Fig. 462 is a side view, Fig. 463 a front view, and Fig. 464 an end view, of a glazier's diamond, mounted with a swivel adjustment for the block when connected with the handle, by means of the screw entering into a gap filed half-way through and across the metal stem. By this means the cut of the diamond is more easily obtained than when the diamond is mounted firmly into its stem; the swivel permitting the block to ply freely, and keeping the cutting edge of the diamond parallel with the edge of the straight rule, or other shaped pattern it is carried along, and thus removing the difficulty of finding its true position, and leaving the workman the task of merely attending to the proper inclination of the handle, as to whether it is carried more or less upright, or leaning to the one or the other side, to suit the cut, and which a very little practice will soon ascertain.

Fig. 462.

Fig. 463.

Fig. 464.

Mr. Turrell thinks that the diamond, in cutting glass, simply acts at first as a burnisher, which compresses a few particles of glass, and then immediately produces the effect of a number of infinitely small wedges, as it were, driven into the glass; the consequence being that the glass naturally separates in the direction of the line in which the diamond was carried. If minute divisions for microscopic purposes be attempted to be made upon glass with the edge of a *cut* and *polished* diamond, however perfect it may be, it instantly splinters up the surface of the glass, even with the slightest pressure, proving it to be unfit for the purpose, owing to the roughness of the edge. But with the natural diamond, the most beautiful lines are produced, and their surfaces so finely burnished, that, when ruled sufficiently close together, they will decompose light, and afford the most beautiful prismatic appearances.[1]

It must not be supposed that, because the ordinary glazier makes one diamond last him his lifetime, that the diamond does not wear out. It is usual to reset the diamond, to expose another angle when one is worn down; and in some glass-works, where enormous quantities of glass are cut up, one or two dozen diamonds are used *every week*.

The following are specimens of diamond tools. The fragments of diamonds (*diamond bort*) are fixed in annealed brass wires, by first drilling a shallow hole for the insertion of the stone, which is embedded slightly below its largest part, and the metal is pinched around it. Shell-lac is also used for cementing in these fragments, and spelter or tin solders may be fused around them with the blowpipe. A turning tool formed of a fragment or splinter of a diamond fixed in a brass wire is shown (magnified two or three times) in Fig. 465, *a*, which is the flat view, *b* being the edge view. Such a tool may be employed for turning the concave and convex surfaces of rubies and sapphires, used for the jewelled holes of chronometers, &c. Such a tool is formed of an egg-shaped diamond split in two, the circular end being used, with the flat surface upwards. With such a tool Sir John Barton engraved the surfaces of hard steel dies in lines as fine as 2,000 in the inch, arranged in hexagons, &c. The gold buttons and iris ornaments struck from these dies displayed the brilliant play of iridescent colours of the originals. By means of such an egg-shaped diamond tool, Sir John undertook to turn off from a cylindrical surface a quantity equal to the 12,000th of an inch: this he accomplished for his friend Mr. Edward Troughton. In drilling rubies, should the diamond drill be too conical, the back part is turned away with a diamond tool, to reduce it to the shape of *c*. For producing very small or very deep holes, a fine steel wire drill, *d*, is used, with diamond powder applied to the end of it. In drilling larger holes in China and glass, triangular fragments of diamond are fixed in the cleft extremity of a steel wire, as *e* and *f*. The china and glass menders also select a tolerably square stone, and mount it as shown at *g*, in the end of a taper tin tube, which wears away against the side of the hole, so as to become very thin, and by the pressure to hold the stone by the portions intermediate between its angles. A similar diamond drill, mounted in brass, has been used with the ordinary drill-bow and breastplate for drilling out the hardened steel nipple of a gun, which had been broken short off in the barrel.

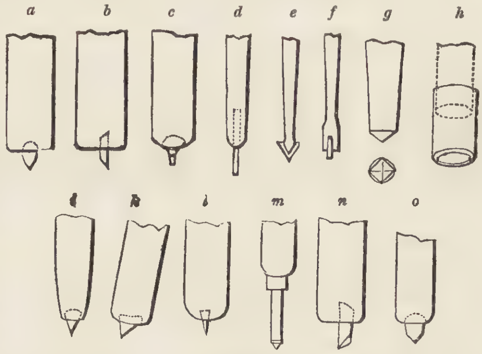


Fig. 465.

For drilling large holes, metal tubes, such as *h*, are used: they are fed with diamond powder, and grind out an annular recess, and remove a solid core.

Some of the lower figures, *l*, *m*, *o*, &c., show the conical diamond used by engravers for ruling medals and other works, and also for etching either by hand or with the assistance of machines used for ruling etching grounds. Conical diamonds are turned in a

(1) Gill's Technological Repository, vol. i. London, 1827.

lathe by a fragment of another diamond, the outside skin or an angle being used; but the tool undergoes almost as much abrasion as the conical point.

For cutting fine lines and divisions on mathematical instruments, a splinter is used, similar to the glazier's diamond; but a fine acute edge is selected instead of the natural angle, which would be too obtuse. *k* and *l* show the side and end views of such a tool.

We shall have occasion in other articles to refer to the use of the diamond. [See HOROLOGY, WATCH-JEWELLING, SEAL-ENGRAVING, &c.]

CHARCOAL is another well-known form of carbon. It is obtained in abundance by the destructive distillation of various organic products, and its appearance and properties vary with its source. If a chip of wood be ignited, the volatile matters burn away with flame, and the carbon that remains retains for some time a red glow; but if, as soon as the flame be extinguished, the chip be inserted in a narrow glass tube so as to cut off the supply of oxygen, the carbon or charcoal will cool without burning away. Charcoal may be prepared by heating to redness pieces of wood in a close vessel, or in a crucible filled up with sand, so as to protect the wood from the destructive action of the oxygen of the air. When all the volatile matters have been expelled, the charcoal remains as a black, brittle, porous mass. A very pure charcoal may be obtained by heating in close vessels sugar and some other substances which do not contain nitrogen; and by passing the vapours of certain hydrocarbons and of oils, alcohol and ether through porcelain tubes raised to a white heat, carbon is deposited in a very pure form.

Charcoal is a black, brittle, insoluble, inodorous, tasteless substance. It is a good conductor of electricity, but a bad conductor of heat. It burns with great ease in oxygen gas, but does not change by the action of air and moisture at common temperatures. When pure, it is infusible at all known temperatures. One of its most valuable properties is that of destroying the smell and taste of a variety of vegetable and animal substances, and of abstracting certain substances dissolved in fluids. Piles are charred at the end before driving, and the coat of charcoal protects them from decay; water-casks are charred on the inside to preserve the water sweet, and charcoal thrown into putrid water will take away its offensive character. Water contaminated with sulphuretted hydrogen is entirely deprived of that offensive gas if shaken up with well-burned charcoal. Charcoal deprives many solutions of colour, and hence is most extensively employed in the refining of sugar. [See SUGAR.] For this purpose the charcoal must be in a state of great porosity, minute division, and with a dull earthy aspect. Hard, brilliant charcoal, even though finely powdered, will not answer the purpose. Animal charcoal is superior to vegetable in discolouring power. Mr. Warington in attempting to decolorize ale, so as to give it the pale tint so much valued in the India market, found that the whole of the bitterness was abstracted by filtering it through animal charcoal. It was afterwards found that the salts of the vegetable alkaloids, such as sulphate of quinia, &c., are abstracted from their solutions by animal charcoal. Several inorganic salts are similarly removed.

Newly-made charcoal possesses the remarkable property of absorbing certain quantities of the different gases. In Saussure's experiments, the charcoal, having been heated to redness, was plunged under mercury, and retained there till cold: it was then introduced into the gas, and kept there for twenty-four hours, when the absorption was at its maximum. Taking the volume of charcoal as unity, the following are the volumes of gas absorbed:—

Ammoniacal gas	90
Muriatic acid gas	85
Sulphurous acid	65
Sulphuretted hydrogen	55
Nitrous oxide	40
Carbonic acid	35
Bicarburetted hydrogen	35
Carbonic oxide	9.42
Oxygen	9.25
Nitrogen	7.5
Carburetted hydrogen	5
Hydrogen	1.75

Aqueous vapour is greedily absorbed by newly made charcoal; and the absorption both of this and of the gases depends in some way upon the mechanical texture of the charcoal, and varies in different woods. Thus, it has been found that, by a week's exposure, charcoal made from—

Lignum-vitæ gained	9.6 per cent.
Fir	13 „
Box	14 „
Beech	16.3 „
Oak	16.5 „
Mahogany	18 „

Wood-charcoal contains about $\frac{1}{50}$th its weight of alkaline and earthy salts, which remain in the form of an ash after its combustion, but the quantity and quality of this ash vary in different trees and plants.

Charcoal dust has been used as a polishing-powder, and it gives a fine polish when rubbed on metals. This property does not belong to every kind of charcoal; but some years ago, Mr. J. Thomson of Glasgow, having been informed that the Dutch rush used in polishing wood owes its power to silex, supposed that wood growing on sandy soils might have the required property, and such was found to be the case. It often happens that turners meet with wood which rapidly destroys the edge of their tools. On converting some of this wood into charcoal, it was found to be well suited to copper-plate workers, &c., as a polishing charcoal-powder.

Charcoal is prepared in large quantities on the Continent, and in countries where wood is abundant and fossil coal scarce. It has been found in the manufacture of charcoal that a much greater quantity is produced when time is allowed for the oxygen and hydrogen of the wood to combine and form water.

The following table contains the results of Karsten's experiments, by which it appears that the slow process of charring is decidedly preferable to the quick. The specimens of wood employed were first dried in the air, and one hundred parts by weight of each being taken, the following figures show the respective weights per cent. of charcoal left, in the one case by the quick, and in the other by the slow, process.

	Quick Process.	Slow Process.
Young oak wood . . .	16.54	25.60
Old	15.91	25.71
Young red beech wood .	14.87	25.87
Old	14.15	26.15
Young white beech wood .	13.12	25.22
Old	13.65	26.45
Young alder wood . . .	14.45	25.65
Old	15.30	25.65
Young birch wood . . .	13.05	25.05
Old birch wood	12.20	24.70
100 years old birch, well preserved	12.15	25.10
Young deal (*P. picea*) ditto	14.25	25.25
Old	14.05	25.00
Young fir (*P. abies*) ditto	16.22	27.72
Old	15.35	24.75
Young pine wood (*P. syl.*)	15.52	26.07
Old	13.75	25.95
Lime-tree wood	13.30	24.60

Several methods are adopted on the Continent for the preparation of charcoal. One is in mounds, with a movable covering, whereby the burner is able to regulate the supply of air. A dry spot is cleared during the summer months, sheltered from the wind by a declivity or a wood, and not far from the place where the wood is felled. The ground is usually covered first with a litter of shingles, planks, or billets, and then with several inches of charcoal powder. The construction of the mound is begun at the centre, by erecting a stake as an axis, from which

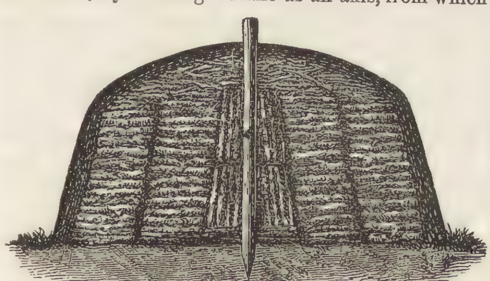


Fig. 466.

the mound is afterwards fired. The stake is a strong post, around which the logs are arranged concentrically; a free channel being left at the bottom, from the stake to the edge of the mound, in order that burning coals may be introduced; or three perpendicular logs are connected together with twigs, so as to leave a kind of open chimney. In either case, the ignition is always commenced from the lower part of the stakes. Partially charred wood from a former process is placed round the stake, and round this the logs, which must be nearly of the same length, and arranged one above another in the form of a ring, leaving as little space between them as possible. All the hewn logs have their sharp edges towards the stake, and the bark side outermost; all spaces occasioned by crooked wood are carefully filled up with small wood. The more slanting the logs are placed, the more loosely will they lie together, and *vice versa;* on which account the external surface of the mound is made as steep as is consistent with the durability of the outer covering. When the logs are laid horizontally, and made to radiate round the stake in one or more concentric rings, many spaces must be left, which require to be filled up, or the combustion and loss would be too great. The best mode of arrangement is to form round the stake a steep narrow mound, as a nucleus, and then to range the logs round this, in the form of a ring, pressing tightly the nucleus, so that its inclination determines that of the whole heap. As the logs are required by the forest laws to be cut of the same length, the upper horizontal logs approach nearer to each other, in proportion to the lessening diameter of the nucleus: thus the external surface forms a series of steps, which are useful in supporting the covering. The upper part of the heap is covered with fragments of wood until it assumes a rounded appearance. A mound may vary from 10 feet in diameter, and even less, up to 60 feet.

When the heap has been *levelled,* that is, all the interstices filled up with small wood, a covering is prepared with moist charcoal powder, which packs more easily and closely together than sand and earth. The first covering is a layer of turf, with the earthy side outermost; or leaves or moss may be used. The turf does not extend quite to the bottom on the edge or *foot* of the mound, but is supported a few inches above the foot by twigs, which are held by forks in the form of a ring against the heap, and are called its *armour.* The open part at the foot is left for the escape of vapour of water, which is formed at the beginning of the process. An opening in the upper part or *cap* of the mound, in the direction of the draught, would promote combustion too much. The second covering of charcoal powder or sand is put over the first, and well pressed down. The mound is then fired, by inserting red-hot coals in the channel at the foot of the mound, or at the top, so that the charred wood about the stake may be ignited as quickly as possible. The opening is then closed up, and the first period begins, namely, that in which moisture is expelled from the wood: this is called the *sweating process.* Great care is required to prevent the too rapid evolution of vapour, which would destroy the heap. During the sweating process, the smoke passes up in a yellowish grey cloud, and a portion of the vapour condenses in the covering, causing it to *sweat,* or to become quite moist. When the smoke becomes grey and lighter, the open part of the armour is covered, and the second process commences. But by this time the wood of the stake has been consumed, cavities have been formed, and the covering, by sinking in, has opened apertures

for the air. The covering is quickly removed, and the wood near the stake broken up and forced together by a long pole: the empty space is filled up with fresh logs, and the covering quickly replaced and stamped down. The combustion of a small portion promotes the dry distillation of the remainder, and the charring, properly so called, begins. The mound is now left for several days, openings being made at the foot to allow the vapour of tar to escape, and to supply the necessary amount of air. The circumference of the heap now diminishes, and the mound must be watched, to see whether the diminution be uniform. If not, the charring has been greater in one place than in another, and a change of direction must be given to the process, by increasing the thickness of covering in those parts, or by making holes exactly opposite to them, which conduct the draught from them to other parts. Before the process is completed, the combustion must be carried to the outside logs, by increasing the access of air, for which purpose a second series of holes is made in the middle part or *breast* of the mound, parallel with those in the foot, but fewer in number. In a short time, the thick black smoke from these middle holes changes into a thin blue cloud: the holes are then closed, and fresh ones made about two feet lower down, when the same phenomena occur. In very large heaps a third series of holes is made close to the lowest openings. If fire issues at the same time all round, the process is known to be successful. Flames are immediately extinguished by moist charcoal powder, and in those places where they do not appear, fresh holes are made, until at length the whole heap is covered up and the process at an end.

As it would require a very long time for the heap to cool, and to break it up at once would cause the charcoal to ignite, a portion of the heap is laid bare at the foot, and the logs are drawn out separately by means of a hook, and immediately quenched by being imbedded in sand or charcoal powder, or by means of water. The hole at the foot of the mound is closed up before the air has had time to produce much effect. This operation is usually performed at night, the darkness enabling the workmen to quench the charcoal more effectually than by day. The time required for charring varies from 6 to 14 days, according to the size of the mound: but with mounds of 30 feet or upwards in diameter, as much as 4 weeks are required. These mounds are very picturesque objects when seen from a distance, and especially from a height, as the Editor saw them a few years ago, in the forests of Bohemia on the borders of the Saxon Switzerland.

Another method of preparing charcoal is shown in Fig. 467. The wood is arranged in the form of a narrow lengthened wedge 20 or 30 feet long, the breadth being occupied by the blocks. The thick or hinder end is from 7 to 9 feet high, and the front or thin end only 2 feet. The heap is arranged on a gentle slope in which the foot slopes towards the back. The heap is begun by driving posts all round the quadrangular space, and within this a floor is formed of long poles placed lengthwise. The logs 8 feet in length are arranged crosswise on this floor, a space 6 inches wide for the covering being left between the posts and the sides of the logs. This space is filled up with planks and wet charcoal powder stamped in until the whole side is covered.

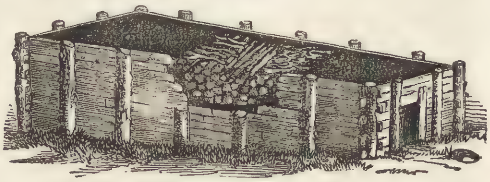


Fig. 467.

A roof is then supplied by a triple covering of twigs, leaves, and lastly, charcoal powder. On the two long sides a number of holes are made in the planks, but not in the covering, and a larger hole in front for introducing the small wood used in igniting. When all is ready, red-hot coals are inserted between the poles and the pile. When the fire has caught, which is seen by the smoke, the hole is stopped up, and other holes, 3 or 4 inches in diameter, are made in front about 15 inches from the ground. The portion of the pile between these now begins to draw whilst the upper and thicker part is sweating. When blue smoke escapes, the process is drawing to a close: the openings are then stopped and fresh ones made higher up, and so on throughout the pile. When the process has advanced to about the length of the logs, the first portions of charcoal are drawn out. It is sometimes the practice to split the logs and place them parallel with the sides of the pile, by which arrangement the carbonization is more readily diffused, and fewer openings are required.

" The process of charring wood," says Dr. Knapp, "which has been known for 2,000 years, belongs to that numerous class of inventions, in which the correct practical discernment of former times has left little to modern theory to supply, beyond the rational explanation. Simple and ingenious as the process is, it has not been modified by any essential improvement. It is impossible to imagine a spot where wood is felled, or to which it is brought by flooding or by wooden sledges, which does not offer the simple requisites for the erection of a mound; and this circumstance is of importance, as the cost of carriage upon wood so far exceeds that upon charcoal. Moreover, wood diminishes in bulk during charring as much as from 20 to 25 per cent., so that a heap comprising 3,000 cubic feet, on being charred becomes 2,250 cubic feet, and a space or hollow of 750 cubic feet would be left, into which the air having access would destroy and waste a portion of the wood. But this cavity is not actually produced, because the flexible covering yields with the wood and prevents any injury from such a cause. No arrangement could so surely and easily regulate the access of air, upon which the main point in the operation depends, as the movable covering. Each thrust of the pole is like opening a stop-cock; each shovel-full of earth

like closing another. Lastly, the fire can be brought to act upon all parts of the mass of wood however extensive it may be, from the peculiar nature of the process. The object of the charcoal-burner is to char by dry distillation the great portion of the wood at the expense of the smaller portion, which in being consumed affords the requisite heat. A certain portion of the contents of the heap must be considered as necessary fuel. Whilst the admitted air partially consumes one log, the adjoining one is exposed to the heat which it evolves, undergoes dry distillation, and is itself afterwards for a short time exposed to the action of atmospheric oxygen. The skill of the workmen consists in accurately observing the time when the air should be prevented having access to the wood, and the neighbouring parts are undergoing decomposition. This part of the operation is greatly facilitated by forcing the vapours, contrary to their usual course, to take a downward direction, and this retards the process, while it enables the workman clearly to discern what changes are taking place, and affords him leisure to take the necessary precautions. The fire, beginning at the middle of the heap, gradually proceeds to the circumference, and thus the nucleus of the heap, which is the first to be completely charred, is protected by an enclosure of burning wood impermeable to air, from the destructive influence of oxygen. One drawback to these positive advantages is the loss of all available secondary products, namely, tar and pyroligneous acid. The sale of these very much depends on the nature of the country, and is often exceedingly small, and yet various methods have been tried, though not always with success, for collecting them. To collect these products from the mound generally does more damage than they are worth. Some have proposed to form the covering of slaked lime, in order to preserve the acetic acid as acetate of lime: others, that it should consist of portable hurdles covered with clay, which being supplied with tubes might carry off the vapours to condensing vessels. This, however, would be depriving the cover of its most useful quality, namely, flexibility. The long masses or piles, Fig. 467, are better suited for condensing arrangements, and the best proposition is, to place a tube in the coating at the thicker end, which shall conduct the vapours to a vessel of water. When it is not necessary to change the spot for the heap, then the base may be built in the form of a flat funnel, the lowest part of which, the middle, is connected with a channel leading to a pit at the side, in which tar and pyroligneous acid may be collected."

Charcoal furnaces have been invented in order to collect these secondary products. In the furnace shown in section Fig. 468, the air has access through the bars *d*, the draught being regulated by a tightly fitting ash-pit door. The wood is put in through the opening at *a* and afterwards through *b*. When the process is complete, the charcoal is taken out through *a*. During the process these openings are bricked up, but the air is allowed to enter through the bars until the walls of the furnace have attained a heat sufficient to complete the carbonization, the doors are then completely closed, and earth is thrown against them, when thick smoky vapours of tar appear.

In Russia, Sweden, and China, carbonization is carried on in pits, the sides of which are made to form the furnace. The pit is usually situated on the side of a hill, and is in the shape of an inverted cone. At the side is a tar-vessel, which is connected with the sole of the furnace by an inclined tube. The pit is filled with finely cleft wood, and the top is then

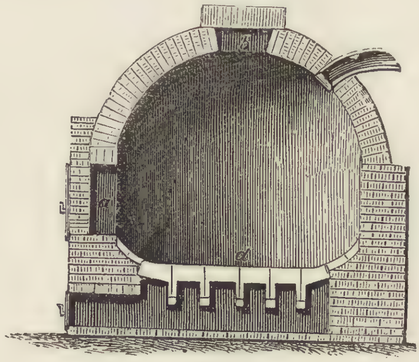


Fig. 468.

closed with a covering of earth, and holes are made in this for the draught. In some cases, air channels are made down the sides of the furnace and enter above the sole. Some further details on this subject will be given under the article TAR.[1]

The charcoal which is left after the distillation of bone is known as *bone-black* and *ivory-black*. [See BONE.] LAMP-BLACK, another form of charcoal, is prepared in large quantities, by the manufacturers of turpentine, from the impure resin and other refuse matters that remain after the distillation of the turpentine. These are burnt in iron pots, or in a furnace, and the dense smoke arising from the combustion is introduced into cylindrical chambers, hung with sheepskin or with sacking, upon the surface of which the soot or lamp-black is deposited. It is swept off from time to time, and sold without any further preparation. A cone of sheet-iron, Fig. 469, hangs within the cylinder: this is pierced at the top with a small hole to allow the smoke to escape, after it has deposited the greater part of its carbon, and when the operation is terminated, this cone is used as a scraper, for, by raising or lowering it, by means of the rope and pulleys, it scrapes against the skin or canvass sides of the chamber, and detaches the lamp-black. The lamp-black thus prepared is not pure charcoal, as it is mingled with resinous and bituminous substances, with salts of ammonia and other matters; but by heating it to redness in a close vessel, all these impurities are driven off, and there remains a charcoal almost pure, for it burns away with scarcely any perceptible residue.

The formation of lamp-black is easily explained.

(1) These details respecting the methods of carbonization practised on the Continent, have been abridged from an excellent work by Dr. Knapp of Giessen, entitled "Chemical Technology, or Chemistry applied to the Arts and Manufactures," translated by Dr. Ronalds and Dr. Richardson. 2 vols. 8vo. London. 1848.

If a gaseous compound of hydrogen and carbon is brought in contact, at a high temperature, with a quantity of oxygen sufficient to combine with its

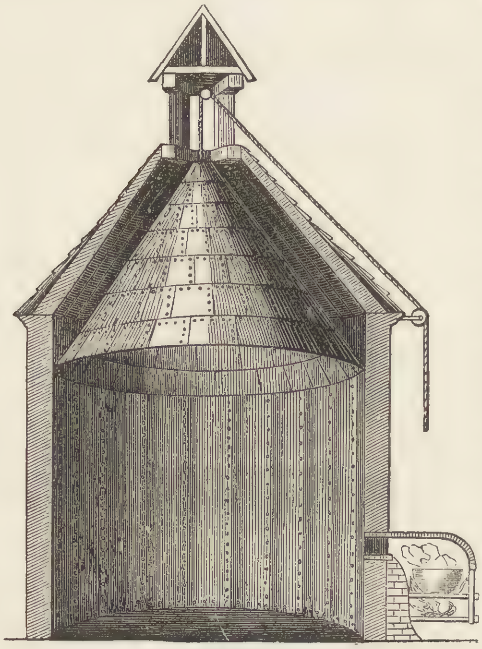


Fig. 469.

hydrogen, but not sufficient to form any compound with the carbon, it is evident that water will be formed, and carbon deposited. The resinous, oleaginous and other substances used in this manufacture are heated to a point sufficient to raise them into vapour, and then this vapour undergoes an imperfect combustion. The chief use of lamp-black is in the manufacture of printer's ink, and for this purpose it has lately been prepared by the combustion of coal-tar.

Dumas gives a description of the manufacture of a coarse kind of lamp-black from some descriptions of coal: it is used in paying ships, and for other purposes where a good colour is no object.

There are other kinds of black used in the arts, such as *Spanish black*, which is the carbon of cork, and *vine-black*, the carbon resulting from the combustion of vine tendrils: these two have a brownish tint; *peach-black*, from peach kernels: this has a bluish tint; *German* or *Frankfort black*, used in making the ink for copper-plate printers, is said to be produced by carbonizing a mixture of grape and wine-lees, peach kernels, and bone shavings.

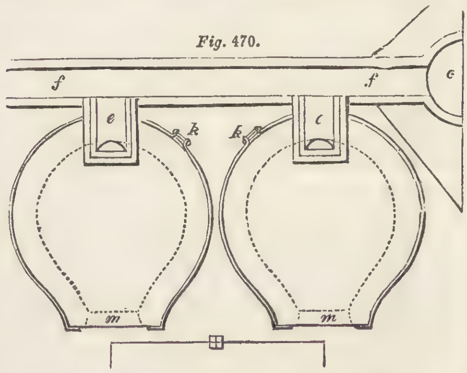
Coal-gas charcoal. In the manufacture of gas, the first products of distillation are sometimes decomposed, and a pure variety of carbon is deposited in layers in the gas retorts. It is of a somewhat greyish colour, it breaks with an earthy fracture, and its sp. gr. is about 1.8. Steel has been made by passing coal-gas over ignited iron, contained in an air-tight iron chest.

Plumbago, Graphite, and Black-lead may also be considered as varieties of carbon. [See Black-lead.]

Anthracite, Mineral Charcoal, Glance-coal, such as the *culm* of Wales and the Kilkenny coal of Ireland, are forms of carbon more or less pure: they do not readily burn, but when ignited, emit no flame or smoke, and leave but little ash.

Coke is the residual carbon of pit-coal, after the volatile matters have been expelled by heat. It has a porous texture, and a lustre sometimes approaching the metallic. It is a valuable fuel, producing an intense and steady heat, leaving very little residue after combustion. As the railway companies are not allowed to produce smoke in their locomotive engines, coke is the fuel employed therein. The small refuse coal which was formerly burnt to waste at the pit's mouth, is now profitably employed in the manufacture of coke; and so great is the demand for this article, that machines are erected for crushing the large coal into small, for the purpose of being made into coke. Small coal is coked upon vaulted hearths with very flat roofs. At the Camden Town station of the North Western Railway, a range of eighteen coke-ovens has been erected, in two lines, on a bed of concrete, the whole of which discharge their products of combustion into a horizontal flue, which terminates in a chimney-stalk, 115 feet high. Fig. 470 is a ground-plan of the ovens, each of which is 12 feet by 11 internally, and having 3 feet thickness of walls; *a a* is the mouth, $3\frac{1}{2}$ feet wide on the outside, and about $2\frac{3}{4}$ feet within;

Fig. 470.



e e are the entrances to the flue: they may be shut more or less by horizontal slabs of fire-brick, resting on iron frames, pushed in from behind, to modify the draught of air. The grooves of these damper-slabs admit a small stream of air, to complete the combustion of the volatilized particles of soot, by which means the smoke is thoroughly consumed. The flue *f f* is $2\frac{1}{2}$ feet high, by 21 inches wide. The chimney *c*, at the level of the flue, is 11 feet internal diameter. *k k* are the keys of the iron hoops which bind the brickwork of the oven. According to Dr. Ure, "each alternate oven is charged, between 8 and 10 A.M. with $3\frac{1}{2}$ tons of good coals. A wisp of straw is thrown in on the top of the heap, which takes fire by the radiation from the dome, (which is in a state of dull ignition, from the preceding operation,) and inflames the smoke then rising from the surface by the re-action of the hot sides and bottom upon the body of the fuel. In this way, the smoke is consumed

at the very commencement of the process, when it would otherwise be most abundant. . . . As the coking of the coal advances most slowly and regularly from the top of the heap to the bottom, only one layer is affected at a time, and in succession downwards, while the surface is always covered with a stratum of red-hot cinders, ready to consume every particle of carburetted or sulphuretted hydrogen gases which may escape from below. . . . The coke being perfectly freed from all fuliginous and volatile matters, by a calcination of upwards of 40 hours, is cooled down to moderate ignition by sliding in the dampers and sliding up the doors, which had been partially closed during the latter part of the process. It is now observed to form prismatic concretions, somewhat like a columnar mass of basalt. These are loosened by iron bars, lifted out upon shovels furnished with long iron shanks, which are poised upon swing chains with hooked ends, and the lumps are thrown upon the pavement, to be extinguished by sprinkling water upon them from the rose of a watering-can; or they might be transferred into a large chest of sheet-iron, set on wheels, and then covered up. Good coals thus treated yield 80 per cent. of an excellent, compact, glistening coke, weighing about 14 cwt. per chaldron. The loss of weight in coking, in the ordinary ovens, is usually reckoned at 25 per cent.; and coal, which thus loses one-fourth in weight, gains one-fourth in bulk."

Fig. 471. COKE-OVENS.

CARBONIC ACID and CARBONIC OXIDE. Carbon and oxygen possess a very powerful affinity for each other when the temperature is sufficiently raised: under ordinary circumstances, and at the usual atmospheric temperatures, they do not combine. The only binary compounds of carbon and oxygen which have been isolated are *carbonic oxide*, which is composed of 6 parts, by weight, of carbon, and 8 of oxygen, and carbonic acid, which contains 6 carbon and 16 oxygen. We will first notice carbonic acid, which is always produced when charcoal burns in contact with air or in oxygen gas: it is also produced by respiration and fermentation. It may be prepared conveniently by the action of muriatic acid on fragments of marble: carbonic acid escapes with effervescence, and chloride of calcium is left in solution.

The gas is colourless, of a pungent odour, and acidulous taste. Its sp. gr. is 1.524, and 100 cubic inches at 60°, and at a pressure of 30 inches as indicated by the barometer, weigh 47.262 grains. This gas extinguishes all burning bodies even when largely diluted with air, for a candle will not burn in a mixture of 4 volumes atmospheric air and 1 volume of carbonic acid. Nor will this gas support animal respiration, for a small portion of it in the air soon proves fatal. An animal cannot live in a mixture which extinguishes a lighted candle, and hence the old practical rule of letting a light down into a well before any one ventures to descend. If the candle burn, it is judged safe, but Dr. Christison relates cases in which a light has not been extinguished, but the men who descended instantly became insensible. When an attempt has been made to inspire pure carbonic acid, there was a violent spasm of the glottis, which prevented the gas from entering the lungs. If sufficiently diluted with air to admit of its passing the glottis, it acts as a narcotic poison. Many persons have lost their lives either intentionally or by accident by sleeping in a confined room with a pan of burning charcoal. Carbonic acid is quite incombustible, and this gas consists of carbon in its highest degree of oxidation.

When lime-water comes in contact with this gas it becomes turbid. The lime unites with the gas, forming carbonate of lime, which being insoluble in water renders the solution of lime-water milky.

Recently boiled water absorbs its own volume of carbonic acid at 60° and 30 inches pressure; but it will take up much more if the pressure be increased. The quantity absorbed is in exact ratio with the compressing force, the water dissolving twice its volume when the pressure is doubled, and three times its volume when the pressure is trebled. On removing the pressure the greater part of the gas escapes, and produces that effervescence which we see when a bottle of ginger-beer, soda-water, cider, or brisk champagne is opened. Water saturated with carbonic acid sparkles when it is poured from one vessel to another. The solution has a pleasant acid taste, reddens litmus paper, but the blue colour returns as the gas escapes. Lime-water is at first rendered turbid by the solution, but it soon becomes clear, as carbonate of lime is soluble in excess of carbonic acid. The agreeable pungency of malt liquors is in great measure due to the presence of carbonic acid, the loss of which by exposure to the air causes them to become stale. Spring and well-water contain carbonic acid absorbed from the air, and to which they partly owe their pleasant flavour. The insipid taste of water that has been boiled is from an absence of carbonic acid. This gas is always present in the atmosphere, even at the height of several thousand feet. Its presence may be proved by exposing lime-water

to the air. A pellicle of carbonate of lime soon forms on its surface. The sources of carbonic acid in the air are numerous. It is an abundant product of combustion, of respiration of animals, which is in fact only a kind of slow combustion, and it is generated by fermentation, and in all those changes which take place in dead animal and vegetable matter. When these processes take place in low and confined situations, the poisonous carbonic acid, or *choke-damp* as it is sometimes called, may accumulate and prove fatal to animal life. But in general this gas is equally diffused throughout the air, and never accumulates unless there is some local source of supply; for although so much heavier than the atmospheric air, the strong diffusive tendency of gases prevents it from separating from the lighter gases of the air. By its equal diffusion it ministers food to growing plants, which decompose the carbonic acid, retain the carbon, and give out an equal volume of pure oxygen in return. Many mineral springs also contain carbonic acid, and in combination with lime it forms extensive masses of rock in all countries. Carbonic acid unites with alkaline substances, forming salts which are termed *carbonates*.

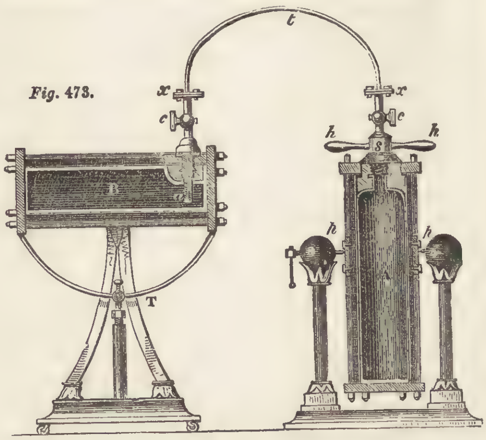
Carbonic acid has been obtained in a liquid, and also in a solid form, the first example of a solidified gas. The liquefaction of carbonic acid was effected by Faraday in the following manner:—A strong tube, Fig. 472, about $\frac{1}{4}$ inch diameter and 8 inches long, being bent at about 2 inches from its end to an obtuse angle, and sealed at the shorter end, sulphuric acid was poured in through a small funnel, so as not to soil the larger leg, which was then loosely filled with fragments of carbonate of ammonia, and also hermetically sealed. The acid was then made to run upon the salt, and the evolved carbonic acid gradually appeared condensed by the mutual pressure of its particles into a liquid form. Many precautions are necessary to guard against explosion; the face and eyes must be protected by a strong mask with goggles for the eyes, and the hands must be shielded by thick gloves. Great care is required in handling the tubes, for in some cases, after having held the fluid safely for weeks together, they have exploded from some slight increase of temperature. It appears from some experiments by Mr. Addams, that the elastic force of liquid carbonic acid at different temperatures is as follows:—

Fig. 472.

Temperature.	Pressure in pounds per square inch.	Atmospheres of 15 lbs. each.
0°	280	18.1
10	300	20
30	398	26.5
32	413	27.6
50	520	34.7
100	935	62.3
150	1,496	99.7

Liquid carbonic acid has been obtained in very large quantities by an apparatus, contrived by M. Thilorier, the principle of which is identical with that of Dr. Faraday's glass tube. The liquid carbonic acid is first produced in a *generator*, from which it is distilled into a *receiver* for the purpose of separating it from the sulphate of soda, &c. The products of several successive operations are collected in this receiver. The generator, A Fig. 473, is a cylindrical chamber of

Fig. 473.



lead enclosed within a copper cylinder, and strengthened by wrought-iron rings. The top and bottom are further strengthened by thick iron plates. The generator is supported on an axis at *p p*. The construction of the receiver B is similar to that of the generator. The opening at *o* in the generator is closed by a screw-plug *s*, pierced in the direction of its axis, and furnished with a stop-cock *c*. The screw-plug is moved by a double handle *h h*. A ring of lead compressed into the double throat between the neck of the generator and the screw-plug, renders the vessel perfectly tight. The receiver B has an opening which is furnished with a copper tube *a*, passing nearly to the bottom of the vessel, and is furnished with a stop-cock *c* on the outside. Communication is established between the two vessels A and B, by means of a copper tube *x t x*.

For the production of the liquid carbonic acid, the following is the charge for a generator 2 feet long, and 4 inches internal diameter:—6.25 lbs. of water at 100°: 2.75 lbs. of bicarbonate of soda in fine powder, and 1.47 lbs. of sulphuric acid of full commercial strength. These proportions leave an excess of alkaline salt, which is desirable in order completely to neutralize the acid. The generator is charged by taking out the valve-plug and introducing some of the tepid water by means of a funnel: the carbonate is then added, then the remaining water, and the whole is stirred up with a rod. The acid is introduced separately in a copper tube, Fig. 474, in order to prevent it from acting upon the materials before the screw-plug is replaced. This being done, the generator is inclined, when the acid flows out of the tube and mingles with the alkaline solution, and in order to mix them more completely, the vessel is turned over and over several times upon its axis *p p*. The generator is then allowed to stand a few minutes erect with its

Fig. 474.

valve end upwards, and the liquefied carbonic acid being lighter than the resulting sulphate of soda, rises and floats upon it. The generator is then connected with the receiver by means of the tube *x t x*, as in Fig. 473, and the valves of both vessels being opened, the carbonic acid passes from A into B. The receiver should be surrounded by cold or iced water, while the generator is allowed to retain its heat. The valves are then closed, the contents of the generator discharged, and the operation is repeated. When the receiver is properly charged, it contains liquid carbonic acid with a quantity of highly condensed gas above it. Upon opening the stop-cock the expansion of the gas forces the liquid up the tube *a c:* a portion of it immediately passes into the state of gas at the orifice, and another portion is frozen into a white snow-like solid, in consequence of the large quantity of heat rendered latent in the passage of the liquid acid into the gaseous state. The solid carbonic acid is blown out in finely divided particles, but it may be collected in a *draw-out box*, Figs. 475, 476. This consists of two parts *a b c d, a' b' c' d'*, which admit of being readily separated and put together again, by one end sliding a little within the other, and held together by two obliquely grooved holders placed on opposite sides of the joint. The lower part *a b c d*

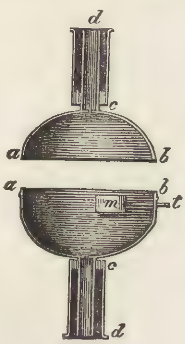


Fig. 475.

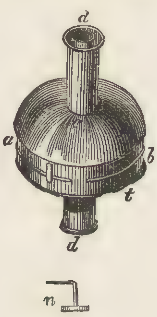


Fig. 476.

has at the side a small tube *t*, which is screwed to the tube *a c* of the receiver, Fig. 473. On opening the stop-cock *c*, a jet of liquid carbonic acid enters the box and strikes upon a small tongue *m*, arranged so as to produce a gyratory motion; the portion of the liquid which becomes transformed into gas, escapes by the central tubulures *c d, c' d'*, while the remainder solidifies within the box.

Mr. Addams has simplified and improved the apparatus for the liquefaction and solidification of carbonic acid gas. The improved apparatus is described in the last edition of Professor Brande's Manual of Chemistry.

Liquid carbonic acid is limpid, colourless and very fluid. Its sp. gr. at 32° is 0.83, and it distils readily and rapidly at the difference of temperature between 32° and 0°. Between 32° and 86° Fahr. the liquid increases in bulk from 20 to 29, which is four times greater than the dilatability of air within the same range. It is insoluble in water and in the fat oils, but it is soluble in alcohol, ether, turpentine, and sulphuret of carbon. Its refractive power is much less than that of water. Some years ago Mr. Brunel attempted to make use of this liquid as a motive power, and the machine which he proposed to construct, to be moved by the expansive force of this gas, was exhibited in diagrams, &c. at the Royal Institution. This machine, however, seems to have failed, for the same reason, as it appears to us, that caused M. Thilorier's apparatus to succeed; namely, by allowing the liquid to escape and assume the gaseous form, so great a degree of cold is produced that a portion only expands into gas, and can be applied as a prime mover, while the remaining portion freezes into a solid. If this really be the explanation of the failure of this machine, and it had been understood at the time, M. Thilorier's beautiful discovery would have been anticipated by twenty years. Solid carbonic acid when first produced, is in the form of a white flocculent powder: it can be melted and resolidified, when it appears clear and crystalline like ice. It melts at −70° or −72° Fahr., and the solid is heavier than the fluid. "At this temperature it has a pressure of about 5.33 atmospheres. It is remarkable for the high tension of the vapour which it gives off whilst in the solid state: there is no other substance which at all comes near it in this respect, and it causes an inversion of what in all other cases is the natural order of events: thus, if, as in the case with water, ether, mercury or any other fluid, that temperature at which carbonic acid gives off vapour equal in elastic force to one atmosphere be called its boiling point; or if (to produce the actual effect of ebullition) the carbonic acid be plunged below the surface of alcohol or ether, then we shall perceive that the freezing and boiling points are inverted; that is, that the freezing point is the hotter, and the boiling point the colder of the two, the latter being about 50° below the former. (*Faraday.*) In the solid state it moves about upon any polished surface, like a drop of water upon white-hot iron, and slowly disappears. Addams found the surfaces from which it had evaporated, in a negatively electrical state. In its usual state the flocculent acid feels like snow, and owing to its low conducting power, it does not evaporate very rapidly, nor feel extremely cold, though its actual temperature is lower than 100° below the zero of Fahrenheit. When a little mercury is put into a saucer and covered by solid carbonic acid, the addition of a few drops of good ether forms a semi-fluid mass, by the contact of which the mercury is immediately frozen: in this way ten pounds of mercury may be frozen in less than eight minutes. In further illustration of the extraordinary relations of this substance, a large lump of the solid carbonic acid was kept for a minute in a red-hot crucible, and afterwards a pound of mercury was frozen with it. When a piece of the solid acid is put into a gas-bottle, it gradually becomes gas, which may be collected as usual over water; or its conversion into the gaseous state may be more strikingly observed, by letting up a small piece of it into an inverted jar of water." [1]

The temperature of the mixture of solid carbonic

(1) Brande: Manual of Chemistry, 1848.

acid and ether in the air, as measured by a spirit thermometer, was found by Faraday to be $-106°$ Fahr., but when this mixture was placed beneath the receiver of an air-pump, and exhaustion rapidly made, the temperature sank to $-166°$ Fahr. In 1845 Dr. Faraday took advantage of this low temperature to resume his experiments on the liquefaction of the permanent gases, which had been undertaken by him with such happy results 22 years before. By using narrow green glass tubes of great strength, powerful condensing syringes, and the low temperature obtained as just described, several of the compound gases were liquefied and even frozen into colourless transparent solids: alcohol did not freeze, but it became thick and oily; while oxygen, hydrogen, nitrogen, nitric oxide, carbonic oxide, and coal gas, could not be liquefied at $-166°$ Fahr. while subjected to pressures varying from 27 to 58 atmospheres.

Carbonic oxide may be obtained from carbonic acid, by subjecting that gas to the action of substances which abstract a portion of its oxygen; as for example, by passing carbonic acid over red-hot charcoal or metallic iron, one half of its oxygen is removed. There are various other methods of obtaining this gas known to the chemist. Carbonic oxide differs essentially in its properties from carbonic acid. It is combustible, burning with a beautiful pale blue flame, producing carbonic acid as the result of combustion. It is colourless, has very little odour, but is very poisonous. It explodes when mixed with oxygen and fired by the electric spark. Its sp. gr. is .973, and 100 cubic inches weigh 30.21 grains.

Carbonic oxide is sometimes produced from the carbonic acid which results from the combustion of coal in our furnaces, and the cause of this is clearly stated in the following extract from an admirable lecture by Professor Miller of King's College.[1] He is tracing the progress of the combustion of a pound of pure carbon.

"When this pound of pure charcoal is burned, when it combines with oxygen from the air, it gives out a certain amount of heat, which, from careful experiment, appears to be sufficient to convert thirteen pounds of water at 60°, the ordinary temperature of the air, into steam at 212°, the boiling-point of water. In other words, it will boil away thirteen pounds of water; and more than the heat sufficient to effect this, no ingenuity can make it furnish. It is evident, however, if it is capable of furnishing this quantity of steam, that unless we actually generate this full amount in our steam boilers,—unless the whole thirteen pounds of water is turned into steam for every pound of charcoal which we consume, that we are incurring a loss greater or less in proportion to the quantity of steam produced. Some waste is almost inevitable; but our exertions cannot be considered to be crowned with the success which is attainable so long as any considerable loss is sustained; we must therefore examine and reflect upon the various circumstances which may produce such loss. The first and most obvious loss arises from the escape of the heated air from the chimney before it has surrendered to the boiler the full amount of heat which it is capable of relinquishing. It is manifest, that the best method of obviating this consists in so arranging the chimney and passages for the products of combustion, that they shall circulate thoroughly around the boiler, and that sufficient time may be allowed for them to part with their high temperature before escaping into the external air. Doubtless this is an extremely difficult thing to effect to the best advantage, and is the part where some loss is inevitable; but it is so striking a point that I need not here dwell longer upon it. Another important source of loss is the cooling down of the pipes and boiler after the steam has been generated, but before it has been used. And here science has rendered most important service; in the Cornish engines especially this point has received attention,—and four times the quantity of work may now be obtained with the same expenditure of fuel from an engine which Mr. Watt considered was doing the full amount of work that could be expected from it. There is, however, another very important but more unsuspected mode in which loss is sustained, and one which is intimately connected with the chemistry of combustion. It depends upon an insufficient supply of air. It is a fact, not less singular than important, that charcoal, or coke, may be dissipated in vapour, and may apparently be wholly consumed, by one half of the amount of air that is usually required in an open fire, under circumstances where the full quantity of heat is given out; and it is to be observed, that in this case one pound of charcoal instead of emitting heat enough to convert thirteen pounds of water into steam, will only give out one-fifth of the heat, and will therefore raise but little more than two pounds and a half of water into steam. This important fact depends upon the property which charcoal has of forming two compounds with oxygen; in the first case where the most heat is emitted, twice the amount of oxygen is taken up, and carbonic acid gas, or fixed air, is produced; in the second case, a gas is obtained also, called carbonic oxide; it is colourless, and therefore escapes notice; but it is combustible, which carbonic acid is not, and in burning, it gives out a large amount of heat; in short, the other four-fifths of the heat which are deficient when charcoal is burned into this gas.

"Now, the way in which this gas is produced is worthy of notice. It is not formed, in the first instance, by the direct union of the coke or charcoal with the oxygen of the air; for carbonic acid is the compound which is invariably obtained; but when this carbonic acid is made to pass over red-hot coals, it dissolves a portion of the coal, becomes dilated to twice the bulk it occupied, and actually, instead of increasing the heat of the furnace by the quantity of coal with which it thus unites, it most materially diminishes it, and carries it off in sheer waste.

(1) An Introductory Address to the Medical Classes of King's College, delivered October 1, 1845; with an Inaugural Lecture at King's College, given October 6, 1845. By W. A. Miller, M. D. F.R.S. Professor of Chemistry, King's College, London. 1845.

I can show you this combination of the incombustible carbonic acid with the combustible coal, and the production of a gas which is capable of taking fire on the application of a light, by passing the carbonic acid through a long glass tube filled with charcoal, and heated to redness by passing it across the furnace, and then collecting in separate vessels the gas which escapes from the apparatus. Now let us consider what is actually going on in many of our furnaces: these are usually open to the air at bottom by the bars of the fire-grate,—brisk combustion takes place, and the body of coke above becomes of a bright red heat; but the air is quickly deprived of its oxygen by the lowest layer of coal, the draught carries up the exhausted air, and with it the carbonic acid that has been formed; this gas, as it passes over the intensely ignited coal, dissolves a fresh portion, cools the fire and ascends the chimney; when it reaches the top of the chimney, it has become too much cooled down to take fire as it comes into the air, and passes off unsuspected and to waste; actually carrying with it four-fifths of the heat that it ought to give out if the coal that it takes off had been burned with a due supply of air. I do not mean to say that the whole of the carbonic acid is ever entirely converted into carbonic oxide; the gas is not in contact with the heated coal for a sufficient length of time to produce this effect; but this I do say, that in all furnaces of the common construction, a large loss is sustained in this insidious and unsuspected manner.

"In the case where coal and not coke is employed, still greater loss is sustained; all the visible smoke is wasted, a good deal of carbonic oxide in addition passes off in the invisible form, and still more coal gas escapes unnoticed; the coal in the upper part of the furnace becomes coked by the heat of the lower portion, and nearly all that the gas-works obtain by distillation of coal in retorts, here passes unheeded into the air. The question, therefore, of the consumption of smoke, resolves itself not merely into a question of health and public convenience, to which too often a deaf ear is turned by those who are deriving profit at the expense of the sufferers, but it is actually a question of economy on the widest scale—it is a question on which common sense and common humanity are alike agreed,—and it is therefore a point which eventually will demand from self-interest, that attention which mere good feeling would long solicit in vain."

CARBURETS. Carbon unites with only a few of the metals forming *carburets*, and of these only one is of importance in the arts, viz. *carburet of iron*, which is contained in the varieties of cast-iron and steel. See Steel.

CARBURETTED HYDROGEN. See Gas.

CARDBOARD. The manufacture of the cardboard which is used for playing cards and for address cards, contains a number of interesting processes, which we will describe in the order in which we recently witnessed them at the house of Messrs. Sabine, Poppin's Court, Fleet Street.

Cardboard consists of a number of thicknesses of paper pasted together, pressed and polished on the two surfaces. Ordinary cardboard consists of two sheets of white paper with a sheet of cartridge paper between them, and the thickness of the board is determined by the stoutness of the paper. For stout cards two or more sheets of cartridge paper are interposed. *Bristol-board*, which is used in sketching, is formed of two or more thicknesses of white paper only. Hence cardboards are known as *three-sheet, four, six*, or *eight-sheet* boards, either *white* or *coloured.* The outer surfaces may be white, blue, green, lavender, or pink, &c., the colours being produced by two outer surfaces of coloured paper. *Enamelled* cards are produced by a process which will be described presently.

For the sake of simplicity we will confine our attention to the manufacture of three-sheet board. The arranging of the paper for this is called *mingling.* That is, a ream of white demy paper is spread open, and between every two sheets, one sheet of cartridge paper is placed; and the pile when complete is called a *head*, consisting, of course, of a ream and a half of paper.

The next process is *pasting.* A man stands at a bench with a mahogany slab before him, the head of paper on his left hand, and a large tub of paste on his right. The paste-brush resembles the broom part of a long-handled hair broom. The operations are conducted as follows:—Pulling the first sheet from the head upon the mahogany slab with his left hand, the paster with his large brush saturated with thin smooth paste covers it with a layer by two or three skilful movements of the hand and arm. He then pulls down upon this pasted surface a sheet of cartridge paper, the top surface of which is in like

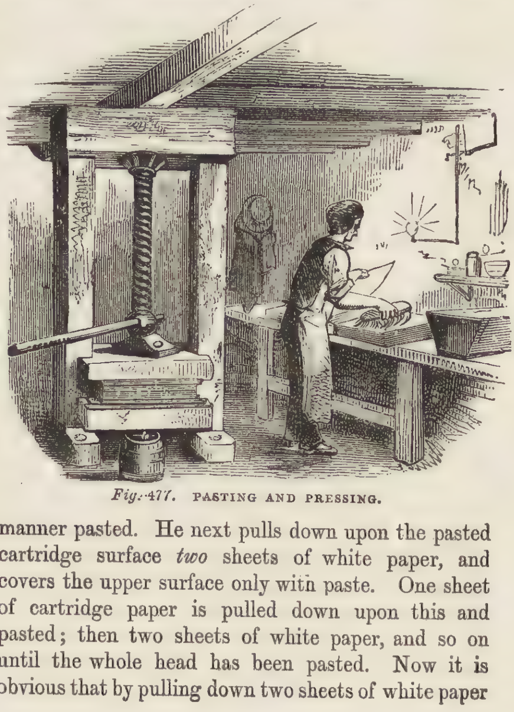


Fig. 477. PASTING AND PRESSING.

manner pasted. He next pulls down upon the pasted cartridge surface *two* sheets of white paper, and covers the upper surface only with paste. One sheet of cartridge paper is pulled down upon this and pasted; then two sheets of white paper, and so on until the whole head has been pasted. Now it is obvious that by pulling down two sheets of white paper

upon a pasted surface, and then covering the upper surface of these two sheets with paste, two contiguous surfaces will be left unpasted, and these form the boundary between every two sheets of cardboard. One man will paste 4 heads of paper, or 7 gross of cardboards, in one day. This will consume about 14 lbs. or 16 lbs. of flour, reckoning 1 lb. of flour equal to 1 gallon of paste. It is not usual to damp the paper previously to pasting, unless papers are brought together which will not *marry,* as in the case of a hard hand-made paper, and a softer and more equable machine-made paper. In such a case the paper must be previously damped in order that the pasted surfaces may properly unite.

When the head has been pasted, it is put into an upright press, and condensed by the action of a well-oiled iron screw, and a long iron lever worked by two men. The water of the paste oozes out at the edges of the head, and falling into a channel in the lower bed of the press, escapes through a hole into a bucket, which becomes entirely filled with clear water from the produce of one man's work in the course of one day.

The next process is *drying.* Every evening before the men leave off work, each man takes out of the press the heads which he has pasted during the day, and placing one of the short sides of the heap before him, he pierces the boards close to the edge with a couple of holes. Then taking up two of the cardboards, he passes a piece of soft copper wire, about $1\frac{1}{2}$ inch long, furnished with a little square of cardboard at one extremity, into each hole. In this way he goes on piercing and threading until the four heads are thus prepared. They are then taken to the drying-rooms, where a number of lines are stretched across near the ceiling, and bending the copper wires into the form of a hook, the boards are thus hung in pairs on the lines to dry. The room is heated artificially, and in the course of twenty-four hours, that is, on the next evening when the lines are wanted for the next day's work, the boards are sufficiently dry. On giving every pair a pull, the soft copper wire straightens, and releases them from the line. They are then separately brushed with a hair brush to remove any dust, &c.

The boards are now rough on the surface, warped and uneven. They are made smooth and even by passing them between a couple of powerful iron rollers in contact with thin sheets of smooth copper plate. The rollers very much resemble those used in bookbinding, [See BOOKBINDING, Fig. 166, p. 155,] and in order that the cardboards may be passed through the rollers square or without overlapping each other, they are placed in a three-sided frame very much like a small dinner tray with the front side left out. A cardboard is first placed in this frame, and upon it a sheet of copper, not quite so large as the board, then another cardboard, then a second sheet of copper, and so on alternately until about a dozen cardboards and as many sheets of copper have been piled up. The bottom roller is furnished with a handle and a fly wheel. The upper roller is movable upon a horizontal axis. A boy is kept turning the handle, and a man takes the pile from the frame and passes it between the rollers, and as soon as it gets within their grip, the resistance is too great for the boy to overcome. The man therefore takes hold of one of the radii of the fly wheel, and pulls it round; the pile passes through, and is received by a boy on the other side; who passes it over the top roller, and the man sends it a second time, and in some cases a third and a fourth time through the rollers. The effect of this rolling is very remarkable. The rough uneven cardboard is converted into a perfectly even board with a beautifully polished glazed surface. Each surface has in fact taken an impression of the smooth, hard, rigid surface of the copper plates, a species of *surface printing,* as simple in its operation as it is successful in its results. The rollers and copper plates are cold, but after passing through the rollers two or three times, the cardboards become sensibly warm to the touch in consequence of the enormous compression to which they have been subjected. While the rolling is going on, two boys are preparing another pile, and when one pile has been rolled, another boy takes out the sheets of copper and arranges the cardboards in a heap.

The cards are now ready for the *stenciller* if they are to be formed into playing cards, or for cutting up into sizes if for address cards. For the latter purpose there are various sizes known in the trade, such as *ladies' size, gentleman's size, trade-card size,* &c. The *large size* card is a parallelogram measuring 4 inches by 3 inches; *one-third large* or *gentleman's size,* is 3 in. by $1\frac{1}{2}$ in.; *ladies' size* is $2\frac{5}{8}$ in. by $3\frac{5}{8}$ in. Then we have *large thirds,* 3 in. by $1\frac{3}{4}$ in.; *outsides,* also called *Cobourg, Town size* or *thirds, extra broad thirds, reduced half large,* all referring to a card which measures 3 in. by 2 in. Then there is *half large,* 3 in. by $2\frac{1}{4}$ in.

The cardboards are first cut into lengths or long strips 4 inches or 3 inches wide, according to the size required. These strips are then cut up with wonderful celerity into cards of one or other of the above dimensions. The cutting is performed by means of an apparatus very similar to the board-cutting machine described under BOOKBINDING, (Fig. 172, p. 157.) The cards are lastly tied up in packets ready for the copper-plate printer.

The enamelled surface of address cards is produced by means of a very pure variety of white lead, known as *China white, Krems,* or *Kremnitz white,* and *Silver white.* [See LEAD.] It is imported into this country in cakes or lumps made up in sealed packets. This substance is stirred up with pure water containing fine sise, made from parchment cuttings boiled down, and rubbed through a sieve by the hand (a most dangerous practice), in order to reduce it to a state of minute mechanical division, and to separate any gritty particles. This mixture is brushed in a thin layer over one surface of the cardboards by means of a large *flat* and closely-set brush, and it is smoothed off by a circular brush made of badgers' hair, which leaves the enamel colour free from streaks

or marks. The cardboards are then placed upon a rack to dry, and in the course of an hour or two, when all trace of moisture has disappeared, the dead white surface produced by the white lead is wrought into a glossy enamel by a very remarkable process. A piece of flannel dipped into the powder of talc (a silicate of magnesia) is rubbed lightly over the surface of the cardboard, the object apparently being to supply every portion thereof with a polishing material. If the flannel were rubbed with much pressure, the already dead white surface would remain so; but when the powder is once applied a strong pressure may be used, and this is given by means of a close-set brush similar to a scrubbing brush, the continued rubbing of which produces the well-known glossy enamelled surface. The great objection to this kind of card is its liability to turn black, the sulphur of the person or of the atmosphere, which is always present in minute quantities in the form of sulphuretted hydrogen, combining with the lead, and forming a sulphuret of that metal, the colour of which is black. On holding one of these cards in the flame of a candle metallic lead is produced in small beads.

Playing-cards are produced by the ancient art of *stencilling*, an art older, in Europe at least, than printing.[1] A stencil is a thin sheet of pasteboard, parchment, or metal, in which the outlines and general forms of the figures are cut out, for the purpose of being stencilled on cardboard or paper. By passing a brush charged with colour over the stencil, the colour enters into the *cut-out* lines, and imparts the figure to the material beneath. The *pips*, or common cards, require only one colour, either black or red; but the *têtes*, or court cards, require many colours. For the production of the former, a thin sheet of cardboard is divided into a number of spaces or parallelograms equal to the size of the playing-cards, and within the first of these spaces, exactly in the centre, the form of an ace, say of diamonds, is cut out; in the second space, a diamond is cut out, near the top and bottom; in the third space three diamonds, and so on up to the ten of diamonds. The stenciller places this stencil-plate upon one of the white cardboards, rolled and polished as above described, and holding it steady with his fingers, rubs in the colour with a large, heavy, circular brush, with closely-set

Fig. 478. STENCILLING AND CUTTING

bristles. A little of the colour, vermilion ground up with sise, is placed upon a board covered with parchment, and upon this the brush is worked until properly charged, and then it is worked upon the stencil with a rotatory dabbing sort of motion, until the forms are properly painted upon the card. For the court cards, several stencil-plates are used, one for each colour. Suppose the ground colour to be red. This goes over the cuffs, and belt, and coronet, and breeches of the knave; a stencil is then applied, which covers all the parts of the card except those which are to be painted yellow: in this stencil, therefore, the cut-out parts fall on the figure exactly where the yellow is to be produced, and this represents the gold lace, the jacket, &c.; a stencil is then applied, to allow of the application of the light brown which serves for the flesh colour; then another stencil for the dark brown that colours the hair: then there is a stencil for applying the light blue which forms orders of courtly dignities, baldrics, and shoe-strings. In this way the cardboards being covered with sets of cards, they are cut up in the same way as the address cards, and with such celerity, that a skilful workman can in two hours and a half cut up 200 packs, of 52 each, or 10,400 cards.

When the backs of the cards are ornamented with spots or small flowers, &c., these are printed in sheets from a stereotype plate, at a common hand-press, and the sheets are attached to the back of the card in the process of pasting.

The duty card, the ace of spades, is printed at the stamp-office, on sheets of thin paper, and supplied to the card-maker as he wants them. Each maker has his own plate, which is engraved at his expense by the Government authorities, and kept by them: he never being allowed even to see it. Each sheet containing aces is of course pasted to other sheets of paper, to make up the proper thickness. It forms the stamp of every pack of cards, and costs the purchaser one shilling. In cards for exportation, a

(1) Mr. Chatto, in his ingenious and entertaining work on the "Origin and History of Playing-cards," (London, 1848,) says that in the oldest cards which he has had an opportunity of examining, and which appear to be of as early a date as the year 1440, the figures were evidently executed by means of a stencil. From the circumstance of so many women occurring as card-painters in the town books of Nuremberg, between 1433 and 1477, it seems probable that they were not wood-engravers, but stencillers. Mr. Chatto thus sums up the history of playing-cards:—"Admitting cards to be of Eastern invention—a fact which appears to be sufficiently established by the evidence adduced in the first chapter—it would seem that they first became known in Europe as a popular game between 1360 and 1390. Covelluzzo, an Italian chronicler of the fifteenth century, says that the game was first brought into Viterbo in 1379; in 1393, three packs of cards were painted by Jacquemin Gringonnem for the amusement of Charles VI. of France; in 1397, the working people of Paris were forbid to play at cards on working days; and in the same year card-playing was prohibited by the magistrates of Ulm. Such are the principal facts relative to the introduction of cards into Europe. The game appears to have rapidly spread amongst all classes of people. The manufacture of cards was a regular business in Germany and Italy, prior to 1425; the importation of foreign cards into England was prohibited by Act of Parliament in 1463; and about 1484, cards, as at present, was a common Christmas game."

drawback of the whole duty is allowed; in which case, the Stamp Office furnishes a different ace of spades, on which a notice is engraved, forbidding the use of such card in Great Britain and Ireland, under the penalty of 20*l*.

It does not appear, from the statements made to us by Mr. Sabine, that card-playing is on the decline. The export trade to the colonies is very large. Mr. Sabine frequently sends 500 dozen packs to one place, and there are other makers in the metropolis whose trade is equally large.

Cards are also produced by printing as well as by stencilling. In 1832, Mr. de la Rue took out a patent for improvements in manufacturing and ornamenting playing-cards; and since that date, other improvements have been introduced, some of which have been made the subject of patents. The following is a brief outline of the process as at present adopted:—

The polish which is communicated to ordinary paper by pressure merely is not sufficient to produce cards of the finest quality. The high finish which is afterwards imparted is produced by a previous preparation of white enamel mixed with size. For printing the pips, sets of blocks are prepared, each containing 40 engravings of one card; and as the ordinary method of letter-press printing is used, 40 impressions of one card are obtained at the same moment. As the pips are either black or red, they are worked at the hand-press, or at one of Cowper's steam printing-machines. The têtes, however, contain five colours, including the outline, viz. dark blue, light blue, black, red, and yellow. These colours are printed separately from a series of blocks, which, if united, would form the intended figure complete: so that, by printing successively from these blocks, the colours fall into their proper places, each colour being made to *register* by means of points in the tympan of the press, or on the engraving.

The printing being completed, the sheets are left during three or four days in a room heated to about 80°, in order to fix the colours. It is of great importance to use such an ink as will not be liable to smear by repeated handling. The colours employed are prepared from the best French lamp-black, for the black, and Chinese vermilion, for the red. These are ground in oil by a machine consisting of cylinders revolving at regulated velocities.

The paper intended for the backs is tinted of the required colour, and printed in various devices by the hand-press or the steam-machine. The *plaid* or *tartan* backs are produced from a block engraved with straight lines, and printed in one colour, which is afterwards crossed with the same or any other colour by again placing the sheet on the block, so that the 2 sets of lines may cross at any required angle. Various other devices are produced by printing with blocks containing various patterns. In printing *gold backs*, size is used instead of ink: the face of the card is then powdered over with bronze-dust, and rubbed with a soft cotton dabber, by which the bronze is made to adhere to those parts only which have received the sise. The backs are also printed from wire woven into a variety of beautiful patterns: the wire is fastened at the ends by 2 pieces of wood, and stretched over a cast-iron block, to which it is fixed by screws. The printing is then conducted in the usual manner.

The pasting is performed after the printing. The printed sheets are either of double or single foolscap, and the cardboards are made 4 sheets thick; *i.e.* the front and the back, with 2 interior sheets of inferior quality. The paste is made as usual from flour and water, heated in a forty-gallon copper to the boiling-point by means of a steam-jacket: this prevents the paste from burning and acquiring a bad colour.

When the pasting is complete, a hydraulic press, of 100 tons, worked by a steam-engine, is used, to express the water from the paste. The cardboards are then hung up to dry, after which they are subjected to the pressure and friction of a brush-cylinder, in which the bristles are short and thick-set: these not only polish the surface, but penetrate into the interior. The best cards are waterproofed on the back at this stage with a varnish, to prevent them from being marked with the fingers in using. Such cards will bear washing without injury. The polishing is completed by passing the cardboards between rollers, one of iron and the other of paper, [see Calendering,] the former being kept moderately warm: they are then passed between 2 bright iron rollers, then milled between sheets of copper, as already described, and lastly flattened, by the pressure of a hydrostatic press of 800 tons. It has been found by experience that the beautiful polish, and perfect smoothness and flatness of these superior cards, can only be produced by a succession of processes, slow in action, and gradually increasing in power. Each cardboard is cut up as before described, first into 8 narrow slips, called *traverses*, each containing 5 cards: these are then cut up into single cards, to the amount of 30,000 daily. The cards, being properly sorted, are made up into packs, for which purpose a number of cards of the same name (probably 200) are arranged on a long table: these are then covered with other cards, and the process is repeated 52 times, with different cards, until the 200 packs are complete. They are then folded up in paper, and tied up. The best cards are known as *Moguls;* others are called *Harrys* and *Highlanders.*

CARDING. See Wool.

CARDING-ENGINE and CARD-MAKING MACHINE. See Cotton.

CARMINE. A beautiful pigment prepared from cochineal. It was discovered accidentally by a Franciscan monk at Pisa, who having formed an extract of cochineal with salt of tartar for the purpose of employing it as a medicine, obtained a fine red precipitate on the addition of an acid. Homberg, in 1656, published a method for preparing it. As the use of this substance in reviving the roses on the cheek of beauty, and concealing the attacks of time, became known, the costly pigment became much in request. The makers of it in some of the principal

towns of Europe, succeeded in preparing different varieties of it of greater or less purity and lustre. Many of these processes, even to the present day, are kept secret; and although the chemistry of the art is well understood, yet there are certain details of manipulation, and an empirical knowledge of the effects of temperature, doubtless acquired after long experience and many failures, which confer on the carmines of some makers a greater lustre than on those of others. The use of carmine has of late years been extended to the manufacture of superfine red inks, of artificial flowers, and to silk dyeing. Carmine is the finest red colour which the painter possesses. It is chiefly used in miniature painting and in water colours. It is made in large quantities in Paris.

Carmine is one of those colours called *lakes*, a term applied to certain colouring substances, which behave like acids and combine by precipitation with a white earthy basis, usually alumina. Carmine is the richest and purest portion of the colouring matter of cochineal isolated in the manner here alluded to. But cochineal contains various colouring matters all capable of acting the part of an acid; these matters are very soluble in water: with insoluble bases they form insoluble salts, but with potash, soda, and ammonia, they form soluble ones. Hence, if cochineal be heated with potash, soda, or ammonia, all its colouring matters will be obtained combined with the base employed in solution with a little albumen. If a quantity of acid be now added, not sufficient to set at liberty all the colouring matters dissolved, the one which has the greatest tendency to unite with the albumen will be precipitated alone, or nearly so.

The manufacture of carmine admits of explanation on these principles. The cochineal is generally boiled with carbonate of potash or soda, and the solution is precipitated by means of a weak acid or an acid salt. If the latter be small in quantity the precipitate is pure carmine, but it forms a powder of such extreme tenuity that it is not deposited by repose only, unless several days be allowed for the purpose. To expedite the process, white of egg or fish-glue is employed, exactly in the same manner as if the object were to clarify the liquid. These two substances in coagulating collect the carmine, and form with it a combination more or less clotty, which is deposited in the course of a few minutes.

The various kinds of carmine are distinguished by numbers, and possess a value corresponding thereto; the difference depending either on the proportion of alumina added in the precipitation, or on the presence of vermilion added for the purpose of diluting and increasing the quantity of the colour: the alumina produces a paler tint, and the vermilion a tint different from that of genuine carmine. The amount of adulteration can always be detected by the use of liquor ammoniæ, which dissolves the whole of the carmine, but leaves the adulterating matters untouched, so that by filtering the solution, and drying and weighing the solid residuum, the amount of adulteration can be detected. The ammonia solution of carmine forms a beautiful transparent colour, making a superior description of red ink.

We give a few recipes for the manufacture of carmine:—

To make ordinary carmine, take 1 pound of cochineal in powder; $3\frac{1}{2}$ drachms of carbonate of potash; 8 drachms of alum in powder, and $3\frac{1}{2}$ drachms of fish-glue. Boil the cochineal and the potash in a copper containing 60 pints of water, the boiling being allayed from time to time with cold water. After boiling for about 20 minutes, the copper must be taken from the fire and placed on a table at such an angle that the liquor may be conveniently poured. The pounded alum is then thrown in and the decoction stirred. It immediately changes colour and inclines to a more brilliant tint. In the course of a quarter of an hour, the cochineal is deposited at the bottom and the liquor becomes quite clear: it contains the colouring matter and probably a little alum in suspension. The liquor is decanted into a copper of the same size as the first, and being placed over a fire, the fish-glue is added: this must be previously dissolved in a large quantity of water and strained. At the moment boiling begins the carmine rises to the surface and a coagulum is formed. The copper must be instantly removed from the fire and its contents be stirred with a spatula. In 15 or 20 minutes the carmine is deposited: the supernatant liquor must then be decanted, and the deposit of carmine drained upon a filter of fine canvas or linen. The carmine ought to crush readily under the fingers. The liquor after the precipitation of the carmine is still charged with colour, and may be employed for making *carminated lakes*, (also called *Lake of Florence*, *Paris*, or *Vienna*.) For this purpose newly precipitated alumina is added to the liquor, the mixture is stirred, and heated a little, but not too much. When the alumina has absorbed the colour, the mixture is allowed to settle and the liquor is drawn off.

The *process of Alxon* or *Langlois* is thus described: Raise 30 pints of river water to the boiling point: then throw in 1lb. of cochineal, and add a filtered solution of 6 drachms of carbonate of soda and 1lb. of water: let the mixture boil for half an hour; remove the copper from the fire and let it cool, inclining it on one side. Add 6 drachms of pulverized alum, stir with a brush to quicken the solution of the salt, and let the whole rest 20 minutes. The liquor, which has a fine scarlet colour, is to be carefully decanted into another vessel: the whites of 2 eggs well beaten up with half a pound of water are to be added and stirred up with a brush. The copper is again to be placed on the fire, when the alumina concreting will carry the colouring matter with it. The copper is to be removed from the fire and left at rest for 25 or 30 minutes, to allow the carmine to fall down. When the supernatant liquor is drawn off, the deposit is placed upon a cloth filter stretched upon a frame, to drain. When the carmine has the consistence of cream cheese it is removed from the filter with a silver or ivory knife, and set to dry upon plates covered with paper to secure it from

dust. By this process a pound of cochineal gives an ounce and a half of carmine.

The process of Madame Cenette of Amsterdam, is said to afford an article of such extraordinary lustre as to fatigue the eye. Into 6 pails-full of boiling-hot river water, throw 2lbs. of the finest cochineal in powder; continue the ebullition for 2 hours, and then add 3 oz. of refined saltpetre, and after a few moments 4 oz. of salt of sorrel (binoxalate of potash). In 10 minutes more, take the copper from the fire and let it settle for 4 hours; then draw off the liquor with a siphon into flat glazed earthen vessels, and leave it there for 3 weeks. There is formed upon the surface a pretty thick mouldiness, which is to be removed dexterously in one pellicle by a slip of whalebone. Should the film tear, and fragments of it fall down, they must be removed with the utmost care. Then decant the supernatant water by means of a siphon, the end of which may touch the bottom of the dish, because the layer of carmine is very firm. Whatever water remains must be sucked away by a pipette. The carmine is then cautiously dried in the shade.[1]

Various imitations of carmine are prepared for the use of those who exhibit rouge on their cheeks. The common rouge of the theatres is prepared by pounding benzoin, red sandal wood, Brazil wood and alum in brandy. The mixture is then boiled until three-fourths of the liquid has evaporated: a paint of an intense red colour remains, and this is applied to the face with a piece of soft cotton. Vinegar is sometimes substituted for the brandy; but as both fluids injure the skin, the colouring matter is sometimes extracted from the dye-woods, and unguents formed therewith, by means of balm of Mecca, butter of cacao or spermaceti. If the colour be too intense it is mixed with chalk.

Rouge dishes are small saucers containing a layer of dry rouge. Those which are prepared in Portugal probably contain genuine carmine: clumsy imitations of these dishes are prepared in London.

Spanish wool and *oriental wool* are also rouge vehicles. Wool is impregnated with the colour, and formed into cakes about the size of a crown-piece by the Spaniards, and somewhat larger by the Chinese: the latter is most esteemed, since it affords (in the language of a modern pharmacopist) " a most lovely and agreeable blush to the cheek."

Beautifully painted and japanned *colour-boxes* are also imported from China. Each box contains 24 papers, and in each paper are 3 smaller ones, namely, a " lovely blushing red " for the cheeks, an " alabaster white " for the face and neck, and a "jet black" for the eyebrows.

French carmine is superior to that of English manufacture, and the superiority is said to depend on the influence of light on its formation and precipitation; the clear sky of the south of France being more favourable for the process than the more hazy atmosphere of England. On this subject Sir Humphry Davy relates the following anecdote :—" A manufacturer of carmine, who was aware of the superiority of the French colour, went to Lyons for the purpose of improving his process, and bargained with the most celebrated manufacturer in that capital for the acquisition of his secret, for which he was to pay a thousand pounds. He was shown all the processes, and saw a beautiful colour produced; yet he found not the least difference in the French mode of fabrication and that which he had constantly adopted. He appealed to the manufacturer, and insisted that he must have concealed something. The manufacturer assured him that he had not, and invited him to see the process a second time. He minutely examined the water and the materials, which were the same as his own, and, very much surprised, said, 'I have lost my labour and my money, for the air of England does not permit us to make good carmine.' 'Stay,' says the Frenchman, 'do not deceive yourself. What kind of weather is it now?' 'A bright sunny day,' said the Englishman. 'And such are the days,' said the Frenchman, 'on which I make my colour. Were I to attempt to manufacture it on a dark or cloudy day, my result would be the same as yours. Let me advise you, my friend, always to make carmine on bright and sunny days.' 'I will,' says the Englishman; 'but I fear I shall make very little in London.' "[2]

(1) " Annales de l'Industrie," Ferussac's *Bulletin*.

CARPENTRY, the art of framing timber for the purposes of architecture, machinery, and all structures in which any considerable weight or pressure is to be supported.

The carpenter who wishes to understand the mechanical principles upon which his art depends, must make himself acquainted with the general laws which regulate the *composition* and *resolution of forces*. The following are illustrations of this important branch of mechanical science.

If a body, or a portion thereof, be at the same time pressed by two forces, in the directions of the two lines A B, A C, Fig. 479; and if the lengths of these lines be in the proportion of the intensities or magnitudes of the two forces; the body is affected in the same manner, as if it were pressed by a single force acting in the direction A D, which is the diagonal of the parallelogram A B C D, having for its adjacent sides the two lines A B, A C. And further, the intensity or magnitude of this single force (or resultant, as it is termed,) will bear the same proportion to the two original forces, that the length of the line A D does to the lengths of the two lines A B, A C. This is called the *composition of forces*.

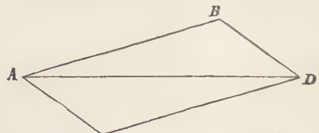


Fig. 479.

Hence, also, a single force or pressure acting in the direction A D, and represented in magnitude by the length of the line A D, may be resolved into two other forces, acting in the directions A B, A C, and represented in magnitude by the lengths of the lines A B and A C respectively; the lines A B, A C, being the adjacent sides of any parallelogram, of which A D forms the diagonal. This is called the *resolution of forces*.[3]

(2) " Salmonia; or, Days of Fly-fishing."

(3) See " Mechanics applied to the Arts," by the Rev. H. Moseley, p 29; also, Hann's " Mechanics for Practical Men," p. 5.

This result may be verified by means of a couple of small pulleys, some thread, and some weights. To the threads A *d*, A F *b*, and A E *c*, Fig. 480, attach the weights *b*, *d*, *c*, and let two of the threads be passed over the pulleys F, and E. The knot A will be drawn in the directions A B, A C, A K. If the sum of the weights *b*, and *c*, be greater than the single weight *d*; the threads will arrange themselves into a certain determinate form: if the knot A be pulled out of its place, it will return to it again, and will not rest in any other position. If, for example, the three weights be equal, the threads will always make equal angles of 120° each, round the knot. If one of the weights be 3 pounds or ounces, &c., another 4, and the third 5; the angle opposite to the thread stretched by 5 pounds or ounces, &c. will always be square. When the knot A is thus in equilibrio, we must suppose that the action of the weight *d* in the direction A *d*, is in direct opposition to the compounded action of *b* in the direction A B, and of *c* in the direction A C. If, therefore, we produce *d* A to any point D, and make A D, on any scale of equal parts, to represent the magnitude of the force or pressure exerted by the weight *d*; the pressures exerted on A by the weights *b*, and *c*, in the directions A B, A C, are equivalent to a pressure acting in the direction A D, whose intensity is represented by A D. If we now measure off by the same scale on A F and A E, the lines A B and A C, having the same proportions to A D that the weights *b* and *c* have to the weight *d*, and if we draw D B, and D C, we shall find D C to be equal and parallel to A B, and D B equal and parallel to A C, so that A D is the diagonal of the parallelogram A B D C. This will always be the case, whatever weights be used, only the weight *d* must be less than the sum of the other two: if any one of the weights exceed the sum of the other two, it will prevail, and drag them along with it. Now, as the weight *d* just balances an equal weight *g*, pulling directly upwards by the intervention of the pulley G, and as it just balances the weights *b*, and *c*, acting in the direction A B, A C; we infer that the knot A is affected in the same manner, by those two weights or by the single weight *g*, and therefore, that two pressures acting in the directions and with the intensities A B, A C, are equivalent to a single pressure having the direction and proportion of A D. So also the pressures represented by A B, A K, are equivalent to A H, which is equal and opposite to A C. Also A K and A C are equivalent to A I, which is equal and opposite to A B.

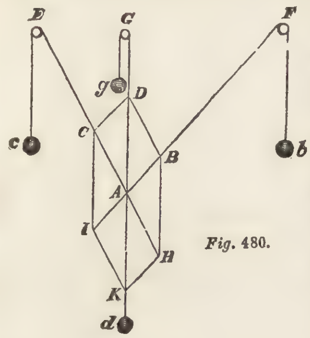


Fig. 480.

To apply this composition of pressures to a case of construction:—Suppose an upright beam B A to be pushed in the direction of its length by a load B; that this beam abut on the ends of two beams, A C, A D, which are firmly resisted at their extreme points C and D, by resting on two blocks: these two beams

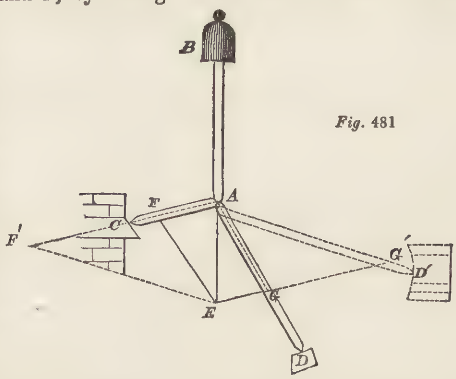


Fig. 481

can only resist in the directions C A, D A, and therefore the pressures which they sustain from the beam B A, are in the directions A C, A D. To ascertain how much each sustains, produce B A to E, taking A E from a scale of equal parts, to represent the number of tons, pounds, or other units of weight in the load B, by which B A is pressed. Draw E F and E G parallel to A D and A C; then A F measured on the same scale will give the number of pounds or other assumed units, which acts as a compressing or crushing force on A C, and A G will give the thrust on A D. The length of A C or A D has no influence on the thrust arising from the pressure of B A, the directions remaining the same; but the effects of this thrust are modified by the length of the piece on which it is exerted. This force compresses the beam, and will therefore compress a beam of double length twice as much, and this may change the form of the combination. If A C, for example, be much shorter than A D, it will be much less compressed: the piece C A will turn about the centre C, while D A will hardly change its position; and the angle C A D will become more open, the point A sinking down. The change of shape resulting from these mutual pressures requires to be carefully studied, for by such a change strains may be produced in places where there were none before, and may tend to break the beams across. The dotted lines show another position of the beam A D′. This greatly increases the thrust on A D′ and A C. That on A D′, now represented by A G′, is almost doubled, and that on A C, now shown by A F′ or G′ E, instead of by A F or G E, is nearly four times greater than before. Thus a very moderate force A E may produce an enormous strain, when it is exerted on a very obtuse angle.

Figs. 482, 483, will show how the same thrusts A F, A G, are made on these beams by a weight hanging from a billet resting on A, pressing hard on A D, and also leaning a little on A C, as in Fig. 482 · or by an upright

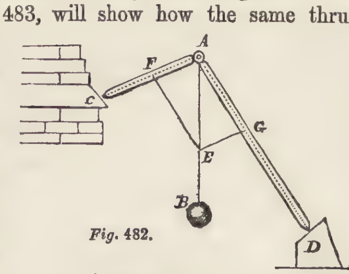


Fig. 482.

piece A E, joggled on the two beams A C, A D, and performing the office of an ordinary king-post, as in Fig. 483. It will of course be seen that the proportions of these forces will be the same, if the system

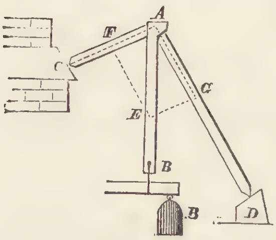


Fig. 483.

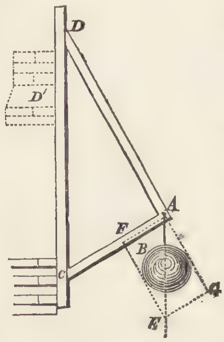
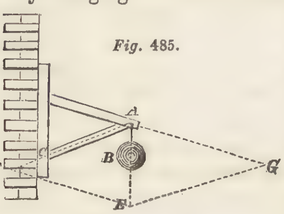


Fig. 484.

be inverted, and each beam be strained or pulled in the opposite direction; that is to say, if the thrusts be converted into strains or tensions. Thus the rope and weight, or loaded beam, instead of being supported by two struts, as in Figs. 481, 482, 483, may be upheld by a framing such as in Fig. 484. Here the batten D A is stretched by a force A G, and the piece A *c* is compressed by a force A F. The magnitudes of these forces remain unaltered, but one of them, A G, is converted from a thrust into a strain.

By changing the form of this framing, as in Fig. 485, we produce the same result as in the system represented by the dotted lines, Fig. 481, and the forces acting on both the battens AD, AC, are now greatly increased. In short, the more open the angle C A G against which the push is exerted, the greater are the forces which are brought on the struts or ties forming the sides of the angle.

Fig. 485.



Should there be any difficulty in ascertaining whether a piece is compressed or extended, whether it is a *strut* or a *tie*, we must consider whether a rope could be employed in its place or not. Thus, in Fig.

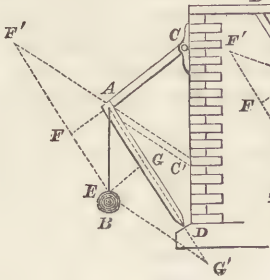


Fig. 486.

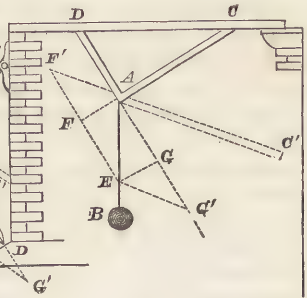


Fig. 487.

486, a rope could evidently be used instead of the piece A C; but A D is a strut butting on the block D, and manifestly could not be replaced by a rope. If A C be placed in the position represented by the dotted lines, the compression of A D is now A G′, and the force stretching A C′ is now A F′, both much greater than they were before. This system is similar to that shown by the dotted lines Fig. 487. There will be no doubt which of these several pieces are subject to tension, and which to compression. A C and A C′, Fig. 486, A D, A C, and A C′, Fig. 487, could be replaced by ropes, and are therefore extended. A D, Fig. 486, could not, and is therefore compressed.

Fig. 487 is the inversion of Fig. 482; and the dotted position A C′, by opening the angle C A D, leads to the same changes as are described in reference to Figs. 481, 485.

Such are the chief varieties in the bearings of three pieces on one point. "All calculations about the strength of carpentry are reduced to this case; for when more ties or braces meet in a point, (a thing that rarely happens,) we reduce them to three, by substituting for any two the force which results from their combination, and then combining this with another, and so on."

The following rule may be given for distinguishing between a strut and a tie:—From the point on which the straining force acts, draw a line in the direction in which this force would move, if left at liberty. Then if this line fall within the angle formed by the two supporting pieces, both pieces are compressed. If it fall within the angle formed by producing the directions of the supporting pieces, then both are extended. If it fall within the angle formed by one piece and the direction of the other produced, then the piece, the direction of which was produced to form the angle, is extended, and the other piece is compressed.

By scientific reasonings such as these, Professor Robison[1] was the first to raise carpentry from a mechanical art to the rank of an applied science. For further information we must refer to his valuable work, and also to that of Tredgold,[2] and pass on to a few general remarks before we close our brief examination of the principles of carpentry.

Since a triangle is the only figure which cannot change its form without altering the proportions of its sides, all frame-work should be arranged in a triangular system, or be divided into triangles, by ties and struts.

When a system of framing is employed to augment the strength of a single beam, such a combination is called a *truss*, and the beam itself is said to be *trussed*.

As a general rule in carpentry, the stiffness or resistance to change of form of any framework, is of greater importance than the comparative strength; which last can be more easily ensured, by increase of or additions to the strength of parts.

But as an universal axiom it must be remembered,

(1) "Robison: System of Mechanical Philosophy." Edited by Brewster. Vol. i. 1822.

(2) "Tredgold: Elementary Principles of Carpentry." Third Edition, by P. Barlow. 4to. London. 1840.

that the strength of no system of framing can exceed that of its weakest point.

Here we may distinguish between the carpenter, and the joiner. The carpenter frames and puts together roofs, partitions, floors, and other essential parts of the building. The joiner only commences where the carpenter leaves off, by supplying and fitting stairs, cupboards, furniture, and other parts, necessary but not essential to the building.

The next branch of carpentry to which we shall devote a brief glance, is that of *Joints*. These may be classed as—

1. Joints for lengthening timbers, by connecting pieces end to end.

2. Framing and bearing joints used in trusses, floorings, &c.

3. Joints for ties and braces.

Timbers may be connected lengthwise, where neatness is not an object, by simply bringing the two beams end to end, placing a short piece on each side, and bolting through these short pieces and the main beams. This form of joint is not neat, but it is simple, and if bolts and straps are well applied, it is as good to resist transverse as longitudinal strains. Ship-carpenters call it "fishing" a beam.

But where neatness is an object, beams are connected longitudinally by *scarfing*. In this case half of the substance of each beam is cut away for a certain length, and the cut portions being brought together, are fastened by screws, bolts, straps, or wedges. In designing the scarf, due regard must be had to the nature of the strain the piece is intended to resist, whether longitudinal, transverse, or both combined.

The common scarf joint, Fig. 488, is made by merely halving each piece of timber for a certain length, and then bolting or strapping the two pieces together. This has evidently no strength in resisting longitudinal strains, beyond that of the bolts and the adhesion or friction between the two timbers which they may cause. But

Fig. 488.

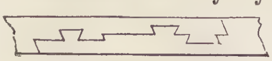


Fig. 489.

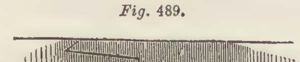


Fig. 490.

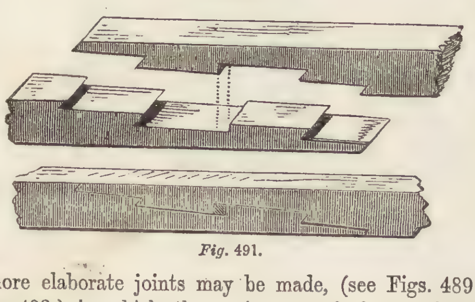


Fig. 491.

more elaborate joints may be made, (see Figs. 489 to 493,) in which the resistance of the wood to splitting is brought in, either with or without bolts, to bear the strain. Figs. 491 and 493, are good examples of this kind of joint. These are to be drawn

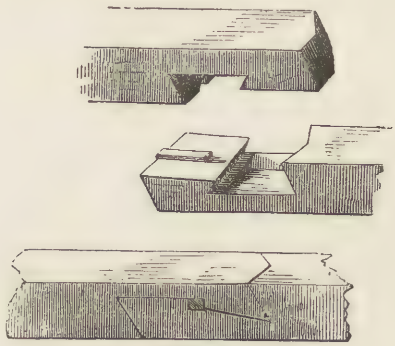


Fig. 492.

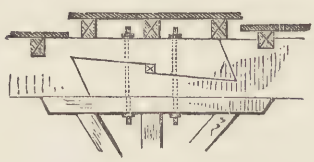


Fig. 493.

together when made by a key or by double wedges. Such a key is shown in the middle of the joint 493, and its place is indicated by dotted lines in 491. Such joints might be used without bolts or straps, but they are far safer with them.

Fig. 494, shows the French scarf called "*traits de Jupiter*," from its fancied resemblance to the form of a flash of lightning. This figure shows the mode of applying bolts and straps. If such a joint were made to

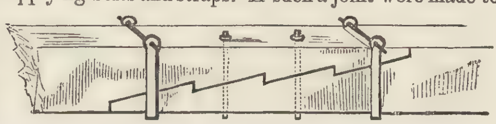


Fig. 494.

resist a transverse and downward strain, it would be better to terminate the upper and right-hand end of the scarf by a plain butt end, of half the depth of the timber, to omit the indents on each side of the centre, and apply a key or folding wedges to the middle indent, making a half dovetail to the lower and left-hand end of the scarf. The reason of this change will be obvious, if we remember, that with a transverse strain the upper surface is only compressed, and the lower surface only extended. The right-hand strap might also in such case, be advantageously removed to the place of the left-hand bolt.

Fig. 495.

Fig. 496.

Figs. 495, 496, show longitudinal joints which may be used where a vertical pressure only is to be borne. The joint is made very short, as the only object is to

keep the two pieces in the same line. In Fig. 496, the end of each piece is divided into nine squares. Five of these being cut away in one piece, and the four alternate squares in the other, the two ends fit into one another.

A common method of scarfing bond and wall plates is, to cut about three-fifths through each piece on the upper face of the one and the under face of the other, about 6 or 8 inches from the end, transversely, forming what is called a *kerf;* and longitudinally from the end, from two-fifths down on the same side; so that the pieces lap together like a half dovetail.

The following brief summary of practice, in scarf joints, is taken from Barlow's "Tredgold's Carpentry."

The length of the scarf should be, if bolts are not used—

In oak, ash, or elm, six times the depth of the beam.

In fir, twelve times the depth of the beam.

If bolts and indents are combined, the length of the scarf should be—

In oak, ash, or elm, twice the depth of the beam.

In fir, four times the depth.

In scarfing beams to resist transverse strains, straps driven on tight are better than bolts.

The sum of the areas of the bolts should not be less than one-fifth the area of the beam, when a longitudinal strain is to be borne.

No joint should be used in which shrinkage or expansion can tend to tear the timbers.

No joint can be made so strong as the timber itself.

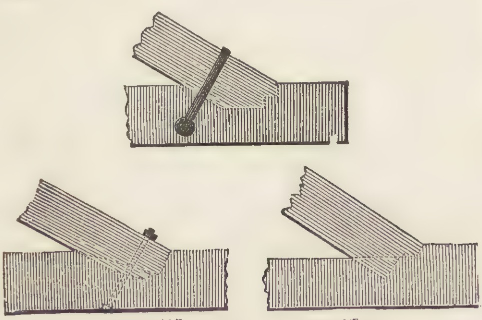


Fig. 497. PRINCIPAL RAFTERS.

Framing joints are those used in the construction of trusses, roofs, centres for bridges, &c. They are universally made on the principle of a *tenon* and *mortise,* that is, one of the pieces to be joined is cut away so as to leave a small projection termed a *tenon,* and a corresponding cavity, called a *mortise,* is formed in the other piece to receive this tenon.

The tenon may be very short, so as not to pass through the other piece, as shown in Figs. 498, and 501. The use of such a tenon is only to prevent any lateral motion in the pieces joined together. Such a joint would be made at the connexion of a king- or queen-post with the principal rafters, (Figs. 499, 500, upper parts of the figures), or of the king and queen-posts with the struts, (see the lower parts of the same figures.) The ends of king- and queen-posts are usually tenoned into the tie-beams. With a similar view, to prevent lateral displacement, the feet of the principal rafters of a roof are tenoned into the tie-beam (Fig. 497). As the pressure in this case is very oblique to

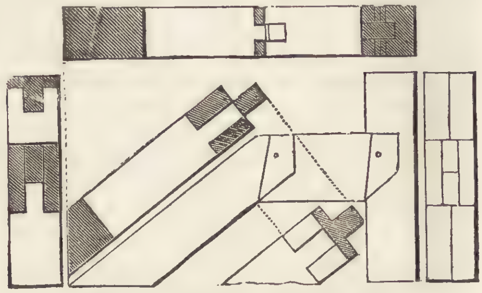
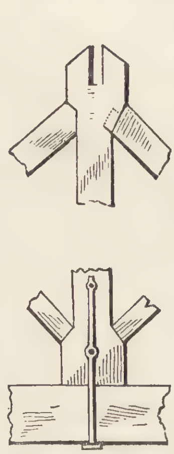


Fig. 498. BEVELLED SHOULDER-JOINTS.



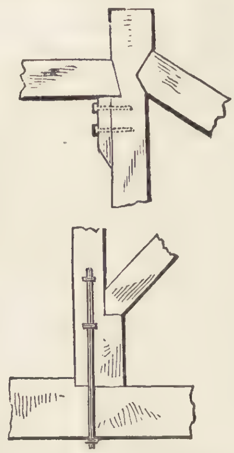


Fig. 499. KING-POSTS. *Fig.* 500. QUEEN-POSTS.

the surface of the tie-beam, a bolt and nut, or, better still, a stirrup-iron or strap, is commonly used, as shown in the figure.

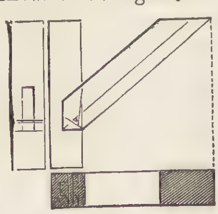


Fig. 501.

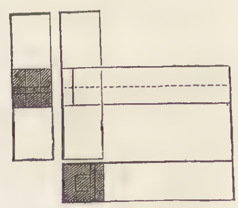


Fig. 502.

A very short tenon, called sometimes a *stub-tenon,* is used at the feet of uprights in partitions and bearers for floors (Fig. 503).

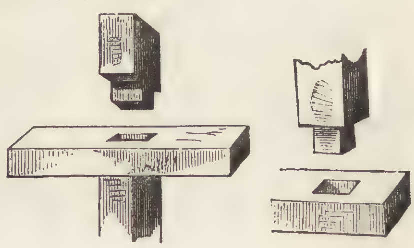


Fig. 503.

When tenons have not only to resist lateral displacement, but also a strain tending to draw them

from their mortises, they must be *pinned* or *wedged*. An oak pin or trenail, or an iron bolt, may be driven through both the tenon and the sides of the mortise, as in Figs 498 and 501; or the tenon may be cut so long as to extend quite through the mortised piece, and have a cross pin passed through the projecting part. The last plan is commonly used in connecting *trimmers* or bridging-joists to the girders or main-joists in floorings.

Wedging is done by making the tenon long enough to pass just through the mortised piece. A saw-cut is made in the projecting part, and a small wedge being driven in, the end of the tenon is expanded, and cannot be again withdrawn from the mortise. If the piece cannot be mortised quite through, *fox-tail wedging* may be adopted. The tenon is made to fit the mortise exactly; two cross saw-cuts are made in its end, and small wedges are put loosely into these. When the tenon is driven down, the wedges meet the bottom of the mortise, are forced into the tenon, expanding its end, and the whole is fixed very firmly. The feet of king- and queen-posts (see lower part of Figs. 499, 500) are commonly tenoned into the tie-beam. Sometimes the tenon is cut to a half dovetail form, and the mortise-hole made to correspond. A key or wedge, driven between the straight side of the tenon and the straight side of the mortise, forces the sloping parts together, and fixes the tenon in its place. A stirrup or strap, such as shown in Figs. 499, 500, is far more trustworthy than such a joint, however well made at first.

Tenons are usually made one-third of the thickness of the timber they are cut from.

Framing and bearing joints should have their bearing surfaces as large as possible, and cut, if possible, at right angles with the direction of the pressure, or (where one piece bears in the direction of its length upon another) in a circular arc, so as to distribute the pressure equally over the bearing surface.

The strength of a structure must never be made to depend on the stiffness of joints, but solely on the arrangement of its timbers. No joint can be made so good as by its own stiffness or resistance to motion to add anything to the strength of heavy framing.

Under the head of joints for ties and braces, we may include joints in wall-plates, purlines, &c. Wall-plates are very commonly joined by dovetailing, as shown in the left-hand figure 504; but they are much

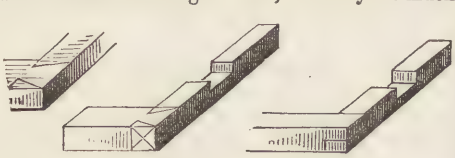


Fig. 504.

better if *halved* together, as in the right-hand figure, and pinned or bolted through. Dovetail joints should, in fact, never be depended upon in carpentry, where the grain of one piece of wood crosses that of the other. Timber shrinks far more across the grain than in the direction of its length: therefore dovetails, however well made at first, are liable through shrinkage to become loose, and thus throw all the strain on the pins or bolts, which were intended only to assist the joint. Dovetails can only be used with advantage when, as in joinery, and in the cases shown in Figs. 507 and 508 (left-hand figure), the grain of both pieces runs the same way. The shrinkage of one then counterbalances the contraction of the other, and the joint remains firm. Such cases rarely occur in carpentry.

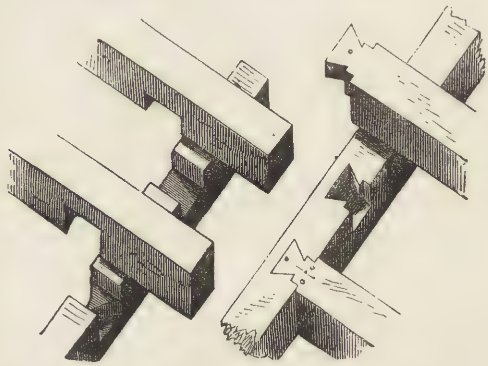


Fig. 505. CAUKING JOINTS.

Tie-beams are connected to wall-plates by *cogging* or *cocking*. A shallow notch is cut out of the under surface of the beam, of the width of the wall-plate, and a similar notch cut in the wall-plate, to receive the beam. The two notches fit together, and all motion, longitudinal or transverse, is prevented. Such a joint is shown in Fig. 505 (left-hand figure). The right-hand figure shows a common way of connecting flooring-joists with trimmers or main joists. As there

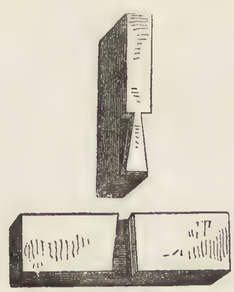


Fig. 506.

Fig. 507.

is seldom in such cases any great force tending to tear the joists from the trimmers, the dovetail form may suffice for all that is wanted. Such a joint would do for a brace between two girders or main joists, where a thrust inwards was alone to be apprehended.

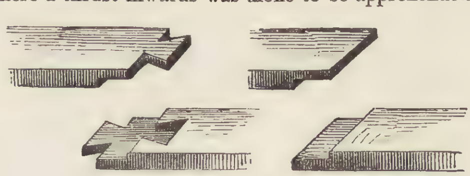


Fig. 508. NOTCHING.

Fig. 509 shows a manner of fitting in a brace on each side of a beam. This joint is only adapted for pressure inward. If any force tending to separate

the pieces be feared, the cogging shown in Fig. 510 may be used.

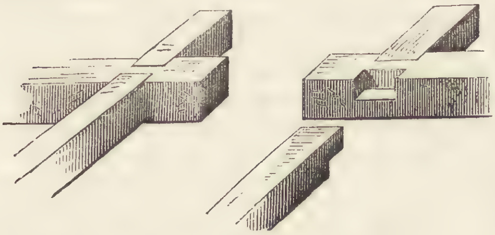


Fig. 509

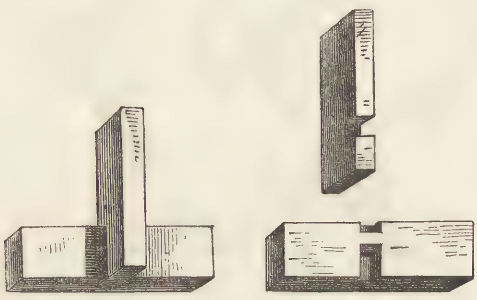


Fig. 510.

Purlines are *notched* down on the principal rafters, as shown in Fig. 505 (left-hand figure).

Fig. 506 shows another application of the dovetail joint, to which the remarks already made will also apply.

Two pieces are said to be *lapped* together, when a portion of each is cut away, and the cut surfaces brought together, as in Fig. 508.

For a more detailed description of the various joints used in carpentry, and an inquiry into their respective values, see Barlow's "Tredgold's Carpentry," quoted above.

For further information on this subject we refer to the articles FLOORS AND PARTITIONS; JOINERY; ROOF; TIMBER;—and to the sections of the article BRIDGE devoted to *Centres* and *Timber Bridges*.

The following definitions of some of the most important terms used in Carpentry, will be found useful.

Wall-plates, also called *raising-plates;* pieces of timber laid on the wall, in order to distribute equally the pressure of the roof, and to bind the walls together, (*a, a, a, a,* Figs. 511, 512).

Tie-beam; (*b b*, Figs. 511, 512) a horizontal piece of timber connected to two opposite principal rafters: it answers the double purpose of preventing the walls from being pushed out by the thrust of the roof, and of supporting the ceiling of the rooms below. When placed above the bottom of the rafters it is called a *collar-beam*.

Principal rafters; (*c, c, c, c,* Figs. 511, 512) two pieces of timber in the sides of the truss, supporting a grated frame of timber over them, on which the covering or slating rests.

Purlines; (*d, d, d, d,* Figs. 511, 512) horizontal pieces of timber notched on the principal rafters, and on which and the pole-plates the common rafters rest.

Common rafters; (*e, e, e, e,* Figs. 511, 512) pieces of timber of small section, placed equidistantly upon the purlines, and parallel to the principal rafters: they support the boarding to which the slating is fixed.

Pole-plates; (*f, f, f, f,* Figs. 511, 512) pieces of timber resting on the ends of the tie-beams, and supporting the lower ends of the common rafters.

King-post; (*g*, Fig. 511) an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters, and at the lower end into the tie-beam: this prevents the tie-beam from sinking in the middle.

Struts; (*h, h, h, h,* Figs. 511, 512) oblique straining pieces framed below into the king-posts or queen-posts, and above into the principal rafters, which are supported by them: or sometimes they have their ends framed into beams, that are too long to support themselves without bending. They are often called *braces*.

Queen-posts; (*i, i,* Fig. 512) two upright pieces of timber framed below into the tie-beam, and above into the principal rafters; placed equidistantly from the middle of the truss or its extremities.

Puncheons; short transverse pieces of timber fixed between two others for supporting them equally; so that when any force operates on the one the other resists it equally, and if one break the other will break also. These are sometimes called studs.

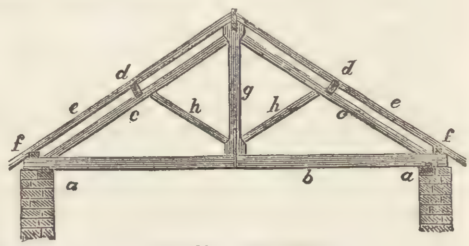


Fig. 511. KING TRUSS.

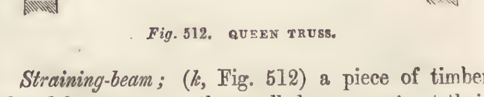


Fig. 512. QUEEN TRUSS.

Straining-beam; (*k*, Fig. 512) a piece of timber placed between two others called *queen-posts*, at their upper ends, in order to withstand the thrust of the principal rafters.

Straining-cill; (*l*, Fig. 512) a piece of timber placed upon the tie-beam, at the bottom of two queen-posts, in order to withstand the force of the braces which are acted upon by the weight of the covering.

Camber-beams; horizontal pieces of timber made

sloping, on the upper edge, from the middle towards each end, in an obtuse angle, for discharging the water. They are placed above the straining-beam in a truncated roof, for supporting the boarding on which the lead is laid: their ends run 3 or 4 inches above the sloping plane of the common rafters, in order to form a roll for fixing the lead.

Auxiliary-rafters; pieces of timber framed in the same vertical plane with the principal rafters, under, and parallel to them, for giving additional support. They are sometimes called *principal braces,* and sometimes *cushion-rafters.*

CARPET. See LOOM—TEXTILE FABRICS—WEAVING.

CARRIAGE. See WHEEL CARRIAGE.

CARTHAMUS or SAFFLOWER, the petals of the *Carthamus tinctorius* or *Bastard Saffron.* It grows naturally in Egypt, and is cultivated largely in Spain and in many parts of the Levant, whence it is chiefly imported. It contains a red colouring matter insoluble in water, and called *carthaméine,* derived probably from the oxidation of a peculiar principle existing in the petals called *carthamine,* and by Dumas, *carthamous acid.* When a weak soda solution of carthamine is left in contact with oxygen, it first becomes yellow and then red, and on saturating this red liquor with citric acid, red carthaméine is thrown down. When air is excluded the alkaline solution remains colourless. "The affinity of carthaméine for cotton and silk is such, that when it is recently precipitated, those substances immediately combine with it, and become at first rose-coloured, and afterwards of a fine red, so that they may be thus dyed without the intervention of a mordant; the stuffs so dyed are rendered yellow by the alkalis, and the colour is to a certain extent restored by the acids. Carthaméine is never used in dyeing wool. When it is precipitated from concentrated solutions, it furnishes a liquid paint, which evaporated upon saucers, leaves a residue of somewhat metallic lustre, used as a pink dye-stuff, and which, mixed with finely powdered talc and dried, constitutes common rouge.[1] [See CARMINE.]

Safflower also contains a yellow substance soluble in water. When the infusion is evaporated it leaves an extract very soluble in water, precipitated by acids and soluble in alkalis. It is not reddened by oxidizing agents.

CARTRIDGE, a cylindrical case of strong paper, (manufactured for the purpose, and hence called *cartridge-paper,*) containing a charge of powder only, (in which case it is termed *blank* cartridge,) or ball and powder, (*ball*-cartridge,) or powder and shot. The use of cartridge is to expedite the loading of small arms. Large cartridges for cannon and mortars, containing powder only, are cased with flannel, pasteboard, or wood. Thin sheet-lead has also been used, and is much to be preferred to the other substances, which are apt to leave burning particles behind in the piece after it has been fired, thus endangering the persons who serve the gun. Wire shot cartridges without powder are also used. They consist of an inner case of wire net-work inclosed in a thin paper case, to the outer end of which a wadding is attached. The shot mixed with bone-dust to fill up the interstices is put into this case, which is rammed down upon the charge of powder. On firing the gun the paper case is immediately torn to pieces, and the shot begin to pass out through the meshes of the net-work, which is carried forward until all the shot are dispersed. By this contrivance the charge leaves the barrel like a bullet, and prevents the leading of the gun,[2] and lessens the recoil. The shot are also carried so much more closely than when loose, that lighter charges and consequently a lighter gun may be used; time is saved in loading, and as the cartridge has no tendency to move until the gun is fired, the danger arising from the accidental shifting or rising of loose charges is avoided.

Mr. Caffin has invented a machine for filling cartridges, which consists of two measures, *m m,* Figs. 513, 514, fixed vertically in a circular plate opposite to each other with an axis between them, on which they work between two other plates. On the top plate *p p* a hopper *h* is fixed, communicating alternately with the measures and filling them; and on the opposite side in the bottom plate *p′* is a hole with a spout *s,* through which the discharge takes place. The plates are framed together by three

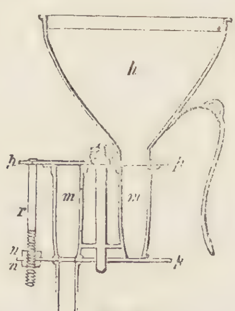


Fig. 513.

Fig. 514.

pillars *r r,* having double adjusting nuts *n n* on each to regulate the distance of the plates. The measures are moved by a handle or lever *l,* the motion of which is limited by the pins *a a,* which, while it presents one under the hopper to receive, places the other immediately over the discharging hole for delivery; so that the two operations of filling and discharging are going on at the same time. The bottom of each measure is slightly contracted to retard in a small degree the discharge, and thus secure the filling of one measure before the other is emptied. A hole is cut in the top plate over the discharging measure, by which it may be ascertained that it is always full, as well as that the whole contents are delivered. A boy delivers with ease

(1) Brande's Manual of Chemistry, p. 1503. See also Dumas, Chimie appliquée, &c. viii. 57.

(2) The streaking of the interior of the barrel by the lead of the shot or bullet.

12,500 measures daily from one machine, and supplies the hopper himself. This machine is also available for measuring seed, corn, or any article in which struck measure is necessary.[1]

CARVING BY MACHINERY is an art designed to save time and cost in the production of decorative wood-work, and at the same time to multiply the copies without lessening the value of original designs. This art is intended to perform the same part with respect to the most beautiful specimens of the wood-carver's skill as copper-plate engraving does for the finest paintings of antiquity. These noble works of genius, confined to their respective galleries, are yet made widely known to the untravelled and unlettered public of all nations through the medium of good engravings; and so may the same public now enjoy, through the wondrous advance of wood-carving by machinery, a sight of that which represents the skill of a Gibbons, or some other laborious artist of former days. It may be said, indeed, that the cases are not parallel; for that, while the engraving can never be confounded with the painting which it represents, nor in any way enter into competition with it, the carving by machinery, being performed in the same material, and with almost identical results, really becomes a *fac-simile* of the original, and must therefore deteriorate its value. Making all allowance for this difference, it yet remains evident that machinery can only imitate, not invent; and therefore the position of the original designer is maintained, while his works are better known to fame by these facilities of repetition. It is also to be remembered that the work of the machine is only partial, and that the finer details are still delivered over to be performed by hand. On the whole, therefore, the invention of wood-carving by machinery must be considered as an advantage to the art, by diffusing more and more widely a taste for works of this kind, by allowing the rarest and best of them to become known, and also by giving employment to a larger number of artists than were previously required.

These benefits are chiefly due to the talent and ingenuity of Mr. T. B. Jordan, to whom the gold Isis medal of the Society of Arts was presented by His Royal Highness Prince Albert, the President, in 1847, for inventing, arranging, and bringing into successful operation such machinery as was capable of producing or assisting in the production of every class of carving, so as to copy accurately any solid form which the mind of the artist can conceive, or his hand execute.

Previously to Mr. Jordan's invention, there had been many attempts of a similar kind, which, from want of economy in production, or from being applicable only to a limited class of subjects, never came into general use. The only machine which has been successfully applied is one for the production of ivory miniatures, copied from full-sized models. The mode of doing this is kept a secret by the inventor, Mr. Cheverton; but the results are exquisite, and are sufficient in themselves to show that works of high art may be successfully copied by machinery. It is conjectured that the means by which these reduced copies are obtained is somewhat on the principle of the pantograph.

The description which follows will assist the reader in comprehending the general method of carving by machinery according to Mr. Jordan's plan; and, as it respects the more elaborate carvings, such as figures, fruits, and flowers, in which a large amount of undercutting is required, apparently beyond the power of any machine to accomplish, we quote Mr. Jordan's own anecdote on that point:—"Our method of accomplishing this undercutting and carving on tne round I cannot better exemplify than by telling you one of the arguments which was very triumphantly used against its possibility, at a scientific meeting at Hampstead, last winter, where I exhibited a few early specimens of our work. Having assured a gentleman present that the undercutting of the specimen he was examining was done on the machine, he smiled, and said 'No: that is not possible: we cannot get a gun to shoot round a hay-mow.' I replied, 'True: but if the engineer takes the liberty of turning the hay-mow about on a point, will not a fixed gun point to every corner of it in succession?'" Thus, whatever the subject may be, there is provision made in this most successful invention for its being completely and cleverly copied, the high finish alone being afterwards put in by the hand of the experienced carver in wood.

The machine, of which Fig. 515 is a pictorial

Fig. 515. CARVING MACHINE AT WORK.

view, and Fig. 516 a front elevation, consists of two principal parts. The first, or horizontal part, is the *bed-plate* and *floating table*, on which the work and the pattern are fixed, all the motions of which

(1) Transactions of the Society of Arts, vol. xlv. 1827.

are horizontal. The second, or vertical part, is that which carries the tracing and cutting tools, the only motion of which, except the revolution of the cutters, is vertical. If, now, the vertical part be placed in contact with the horizontal, while the latter is moved about horizontally, in all directions, a figure will be described on the latter corresponding to the direction of its motion, as if, in drawing with a lead pencil, the pencil were fixed, and the paper moved about against it. Such is the principle of Jordan's machine. We shall now describe its parts separately.

The horizontal part consists of three castings:—*first*, the bed-plate A B C D, which is a railway permanently fixed to the floor of the shop, and made perfectly horizontal; *secondly*, a carriage or frame, I J K L,

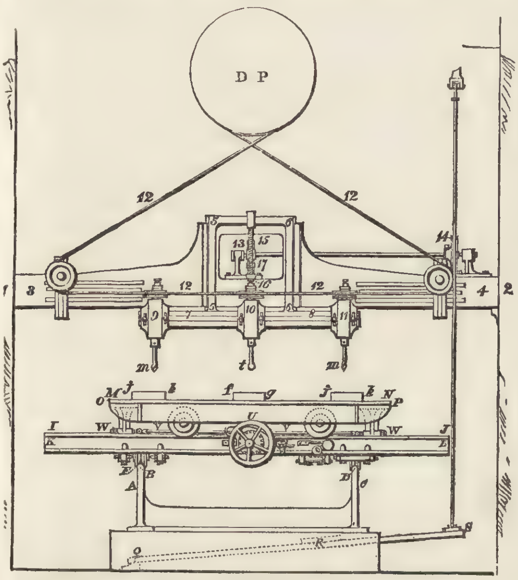


Fig. 516.

running on this railway, supported by four wheels, of which only two are seen, F D; *third*, the horizontal table, M N O P, which carries the work, and is called the *floating table*: this is furnished with four wheels, running on the frame I J K L, but its motion is at right angles with the motion of the frame. We are thus enabled to move the floating table either laterally, on its own wheels, or straight forwards or backwards, by the frame I J K L, and thus bring any point in the floating table to any point in the same plane with it. The workman moves the floating table from right to left with his left hand by the wheel U, and the table and frame are both moved backwards and forwards with his right hand on the horizontal wheel, as shown in Fig. 515.

The second or vertical part of the machine consists of a bridge or fixed support, 1 2 3 4, in which a bar, 5 6, slides up and down, with another, 7 8, fixed to it. To the latter are attached any required number of mandrils, 9, 10, 11, one of which carries a blunt tool or *tracer*, Fig. 517, which is fixed, and the others carry each a cutting tool, Fig. 518, (calculated by their revolution to describe the shape of the tracer.) These tools are made to revolve from 5,000 to 7,000 times a minute by means of an endless band, 12, driven by steam. The model *f g* is fixed on the floating table

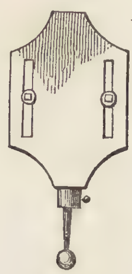


Fig. 517.

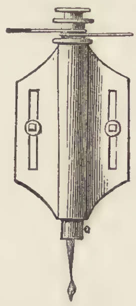


Fig. 518.

under the tracer, and a piece of wood, *j k*, or other material to be carved, is fixed under each cutter. The cutters and tracer are adjusted to the same level, and the steam is turned on. The man presses on the pedal R S, which acts by means of a horizontal bar carrying two pulleys, 13 and 14, on the slide, and lowers it to the work. There is generally a weight to counterbalance the slide, so that it cannot press heavier than is desirable. 15 is a stop screw, which regulates the range of the slide, to which it is fixed. It passes through a free hole in the bracket 16, which serves as a stop to the locking-nuts 17, and these may be fixed on any part of the screw, so as to determine the distance through which the slide shall move. In very large machines the workman has a greater command over the floating table, by means of a steering-wheel U, and its axle, which passes across the centre of the lower rolling frame, and is furnished with a drum 3 or 4 inches in diameter, about which is coiled the centre portion of a wire line V V, while its ends are fixed to screws W W, which pass through sockets cast on the floating table; so that, by turning the steering-wheel to the right or left, a corresponding motion will be given to the work just inside the steering-wheel; and on the same axis there is a small cogged wheel, which serves to fix the axle, and consequently to stop the motion from right to left when the detent shown in the figure is dropped into its cogs. There is a similar steering-wheel and detent for the other motion; but the detents are only used when straight lines in one direction are required. The workman moves the floating table about, so as to bring every part of the pattern under the tracer, and as the slide can only move vertically, whenever the tracer comes to a depression it goes down, and the cutters cut a similar depression in the blocks. If there be an elevation in the model, it lifts up the tracer, and with it the cutters, and thus an elevation of the same height is left in the blocks; and in this way the work proceeds, the tracer gliding silently over the model, and the cutters cutting away with some noise on the blocks, until the pattern is finished. The more accurately the model is to be copied, the more delicate are the tools employed; but it is generally desirable to perfect the work by hand, as there must necessarily be little delicate portions which it is impossible for a machine to perform cor-

rectly. Such is the method employed in common carving; but when a large amount of undercutting is required, some modifications of the machinery are necessary. These consist either in placing the wood to be cut between two centres or chucks on the floating table, and turning it round, so as to get at all the parts in succession, or in using crooked tools and tracers, something like inverted mushrooms, when a small amount only of undercutting is required. As a proof of the value of Mr. Jordan's machine, we may mention that the beautiful and elaborate wood-carving which adorns the new Houses of Parliament has been produced by its means.

CASE-HARDENING, an operation of great importance in the arts, whereby a thin casing of steel is given to iron, and the steel can be hardened to that particular depth, leaving the central parts in their original condition of soft fibrous iron or of cast-iron.

Steel is formed by the chemical combination of a small proportion of carbon with iron. In case-hardening the carbon is communicated to the iron by means of certain animal matters, such as the hoofs, horns, bones and skin in a charred or coarsely pounded state, sometimes with the addition of a little salt. The works to be case-hardened should be surrounded on all sides with a layer from $\frac{1}{2}$ to 1 inch thick.

In case-hardening a gun-lock, for example, the work is inserted into the bone-dust contained in a sheet-iron case; the lid is tied on with iron-wire, and the joint luted with clay: it is then heated to redness as rapidly as possible, and kept at that heat for half an hour or an hour. The contents are then quickly immersed in cold water. The effects intended to be produced are a steely exterior, and a clean surface covered with mottled tints caused probably by oxidation.

Some malleable iron-castings, such as snuffers, &c., are case-hardened, because in that condition they admit of a better polish. They should be left in the burnt bone-dust at a dull red heat about 2 or 3 hours, and should be quenched in oil, which renders them less brittle than in water. Thin articles are sometimes not only case-hardened, but entirely converted into steel of an inferior kind, which makes them very brittle.

For large works the process is continued from 2 to 8 hours, and is even repeated a second time with new materials. In some cases the work is immersed in water directly it leaves the furnace: in others the box is allowed to cool without being opened, and the pieces are hardened by a subsequent operation. [See HARDENING and TEMPERING.]

When the case-hardening is required to terminate at any particular part, as a shoulder, &c., the object is left with a band or projection, and the work is allowed to cool without being immersed in water, the band is turned off, and the work when hardened in the open fire is only affected where the case-hardened surface is left.

A salt known as prussiate of potash ($C_2 + N$) has of late years been used for case-hardening, and it shortens the time required for the process from hours into minutes. For example, the iron is heated in the open fire to a dull red-heat, and this salt is either sprinkled upon it or rubbed upon it in a lump: the iron is then returned to the fire for a few minutes, and then immersed in water. By rubbing the salt upon any particular part of the article, that part alone is case-hardened. By this process the case of steel is exceedingly thin, and it is even said to be not continuous.

In most cases the thickness of the steel does not exceed $\frac{1}{16}$th inch, nor is it necessary that it should be thicker, the object being to obtain durability of surface with strength of interior. The steel obtained in this manner is not equal to that which is converted and hammered in the usual way. [See STEEL.]

CASHMERE, a beautiful fabric manufactured in the kingdom of Cashmere, from the fine wool growing about the roots of the hair of the Thibet goat. Cashmere shawls have a wide-spread fame, on account of their extreme softness, brilliancy, and elegance; and it has long been the aim of European nations to imitate, and if possible to equal them, applying to their manufacture the more speedy and elaborate methods which modern science has placed within reach. The oriental shawls are woven by an extremely slow process, and are therefore very costly. The date of the manufacture is unknown, but these shawls have been celebrated ever since the British established themselves in India. As far as we can gather from the observations of various writers, the Thibetian wool, being imported from Thibet and Tartary into Cashmere, is first bleached to rid it of a greyish hue which naturally belongs to it, then spun into yarn by women, and dyed of various colours. The yarn is next given out to the weavers by a merchant, who perhaps enters largely into the shawl trade, and engages a number of shops in which men work for him; or else he supplies a certain number of overseers called Oostands with yarn, delivering to them at the same time instructions as to the quality, colour, patterns, &c. of the goods, and these men carry on the manufacture at their own houses, with the help of ordinary weavers. The Oostands receive six or eight *pice* a day for their wages, the common workman from one to four *pice*, the value of a *pice* being about three-halfpence. Thus scantily are the shawl weavers of Cashmere rewarded, while the fabric they produce has often been sold in London at from 100*l*. to 400*l*. the shawl. But it is fair to state that the manufacture of a remarkably fine and elaborate shawl will sometimes occupy a shop for a whole year, two or three or perhaps four persons being constantly engaged on it. Plain shawls are simply woven with a long narrow and heavy shuttle, but variegated shawls are worked with wooden needles instead of a shuttle, there being a separate needle for each colour. In some of the richest shawls, scarcely a quarter of an inch is completed by three persons in one day. Sometimes, in order to hasten the process, a shawl is

made in separate pieces at different looms, and the pieces are afterwards sewed together. This is done with great dexterity, so that it is not immediately detected. An overseer at each loom superintends the workmen, and if the pattern be new, he directs them as to the figures and colours, keeping before him a paper pattern of the device which is to be produced. The rough or inferior side of the shawl is uppermost on the frame, nevertheless the pattern is most accurately preserved by the workers, who sit on benches while so employed. The shawls are made both long and square, the former generally measuring 54 inches wide, and 126 long, the latter 63 to 72 inches square. They are exquisitely soft and warm, surpassing in these respects every other clothing material. In some parts of Asia these shawls are worn just as they come from the loom; but all those destined for India are carefully washed and packed near Lahore. The extent of the manufacture in Cashmere has been differently stated: some years ago there were said to be 16,000 looms in that kingdom; and if it be correct that about five shawls (including the inferior qualities) are made on an average at each loom during the year, this gives a total of 80,000 shawls as the annual produce of the kingdom. When Cashmere was tributary to Afghanistan, a considerable portion of the revenue was exacted in shawls instead of money.

The beauty and value of Cashmere shawls has led to various imitations, which at length have proved successful, both in France and England. The government of the former country gave encouragement to a patriotic and zealous man, M. Jaubert, who exposed himself to great risk and hardship, in bringing from the East in 1823 a flock of Thibet goats, part of which were successfully reared at St. Ouen, near Paris. The climate suited them well, so that for several years the proprietor was enabled to sell a great number of male and female goats, which were called Cashmere goats.

At the time when the flock first arrived in Paris, an English gentleman (Mr. Taylor) was so fortunate as to obtain four of the goats by purchase. These he safely conveyed to Essex, and, placing them in his park, they continued in health, and steadily multiplied, until, in 1828, the number had increased to twenty-seven, and, in 1833, to fifty. The coat of these animals was a mixture of long coarse hair and of short fine down. The latter became loose early in April, and was easily collected by combing the goats two or three times; but the down produced was very small in quantity, not more than four ounces being obtainable each season from a male, and two ounces from a female. This circumstance, which made it hopeless to cultivate the Cashmere goat for any profitable purpose, led to a mixture of the Cashmere breed with another breed with abundant silky hair, introduced into France a few years later, and called Angora goats. The progeny of the two, called Cashmere-Angora goats, were found to possess a considerable quantity of long silky down, admirably fitted for the purpose of shawl-weaving. Some of these goats yielded as much as thirty ounces of down per goat, while the animals were more robust and easily nourished than the pure Cashmere. From these experiments great good has resulted in the improvement of various flocks. For instance, ten male and three female Cashmere-Angora goats were shipped for South Australia, where the wool trade has become highly important, from the judicious importations of fine Saxon and other flocks into that country. The Cashmere wool still imported from Thibet comes into Europe by way of Casan, on the eastern bank of the Volga. The mills for spinning it are very numerous in France, where three principal descriptions of Cashmere shawls are manufactured, at Paris, Lyons, and Nismes. The Paris shawls are principally of the kind known as French Cashmere, in which, by the aid of the draw-loom and of the Jacquard, a surface appearance is given precisely similar to that of the oriental shawls. Both the warp and the weft are the yarn of pure Cashmere down: the figures and colours of the Indian shawls are faithfully copied, and the deception would be complete, did not the reverse side show the cut ends. What is called the Hindoo shawl, manufactured at Paris, has its warp in spun silk, which reduces the price. These imitation shawls are executed by as many shuttles as there are colours employed, which are thrown across the warp according to the requirements of the pattern, and being in many cases introduced only at intervals, the yarn remains floating loose at the back of the piece, and is cut off afterwards.

To contrive a method of weaving shawls that should be, like the eastern ones, both sides alike, was a difficult task, but was at last accomplished by Parisian ingenuity. In this case, the yarns of the weft are not only equal in number to the colours of the pattern, but there are also as many little shuttles or pirns filled with these yarns as there are colours to be repeated in the breadth of the piece. Each of these small pirns or bobbins passes through only that portion of the flower in which the colour of its yarn is to appear, and stops on the one side and the other of the cloth exactly at its limit: it then returns upon itself, after having crossed the thread of the adjoining shuttle. From this reciprocal interweaving of the various yarns of the shuttles, it happens that, although the weft is made up of a great number of different threads, yet they form a continuous line in the whole breadth of the web, upon which the lay or batten acts in the usual manner. The great art consists in avoiding confusion of the shuttles, and in not striking up the lay till all have done their part. A woman assisted by two girls is able to conduct the whole operation. But this close imitation of the oriental shawl is a very slow process, and therefore the shawls must be necessarily costly. Lyons is famous for its Thibet shawls, the weft of which is yarn, with a mixture of spun silk. The shawls of Nismes are celebrated for their low price and the ingenuity with which spun silk, Thibet down, and cotton are all worked up together.

CASK. See Coopering.

CASSAVA. See Starch.

CASTING and FOUNDING. The valuable property of fusibility possessed by many of the common metals, admits of their being poured in a fluid state into moulds of various kinds, so that on again becoming hard by cooling, the castings are the exact counterparts of the moulds. In casting ingots, flat plates, and a few other objects, open moulds are used; but metals are generally cast in close moulds which must contain apertures or *ingates*, for pouring in the metal and for the escape of air. If the moulds be of metal, they must be warmed before pouring, so that the fluid metal may not be chilled and solidified before it has filled every part of the mould; and when the moulds are of earth or clay, the moisture which is necessary in forming them must be expelled before the time of filling. Earthen moulds must also be porous, to allow of the escape of any vapours or gases which may be generated at the time of pouring, otherwise the molten metal may be driven out with a violent explosion, or some of the bubbles of air will displace the fluid metal, and render it spongy or porous, in which case the casting is said to be *blown*. Sand is sufficiently porous to allow of the escape of vapour. In the greater number of cases moulds consist of two parts only: in other cases they are divided into many parts.

When an object is to be cast, it is often necessary to form an exact pattern in wood, and the success of castings depends greatly on the skill of the pattern-maker. Deal, pine and mahogany with a straight grain are the best woods for making patterns. In putting the parts together, screws are preferred to nails, but glue-joints, such as dovetails, tenons, dowels, &c. are also used. The patterns are made to taper a little in the parts which enter most deeply into the sand, so that they may be easily removed. Sharp internal angles should also be avoided, as they leave a sharp edge or axis in the sand which is liable to be broken down in the removal of the pattern, or injured by the rushing in of the fluid metal. All glue must be carefully scraped off, or it will adhere to and pull down the sand. The patterns should either be painted, varnished or well brushed with black-lead. Foundry patterns are sometimes made in metal, and when of iron they are allowed to get a little rusty, and then warmed sufficiently to melt bees'-wax, which is rubbed over them; after which most of the wax is removed by polishing with a hard brush. Wax is also used for stopping up any little holes which may exist in wooden patterns. Whitening is also used for the same purpose. Metal patterns must sometimes have holes tapped in them for receiving screwed wires which serve as handles for lifting them out of the sand. Large wooden patterns also have screwed metal plates let into them for the same purpose.

The moulding-sand is supported by shallow iron frames without tops or bottoms called *flasks*. The bottom 4, 5, Fig. 519, is supposed to be rammed full of sand, and to stand upon a flat board 6. The model of the flat bar shown in the figure which is to be cast is laid on the surface of the sand, and that of the round bar is embedded half way therein. The mould is then dusted with dry *parting-sand*. The top part of the flask 2, 3, is shown still empty, and in the act of being attached to 4, 5, by its pins, which fit exactly into corresponding holes in 4, 5. The part 2, 3, is also rammed

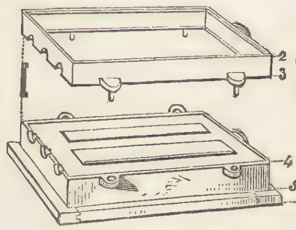


Fig. 519.

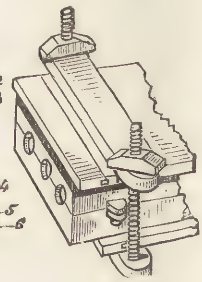


Fig. 520.

full of sand and covered with a top board 1, not shown in the figures. The sand of course receives the impression of the patterns, and when the mould is opened, the models are removed, and channels for the escape of air are scooped out from the ends of the cavities left by the models, to the hollows or pouring holes at the end of the flask. The parts are then replaced in the order 1 to 6, and the whole are fixed together as in Fig. 520. The flask is then placed almost erect near the pouring trough, and the metal is poured in from a crucible, as shown in Fig. 222, [see BRASS,] but if the flask be small, it is propped up with a short bar on the surface of the pouring or spill trough.

The flasks or casting boxes are of various sizes, and the depth of each side is about 2 or 3 inches. For small castings they are poured at the edge as already explained, but for large castings they are generally poured horizontally through a hole in the top. The tools used in making the moulds are a sieve, shovel, rammer, Fig. 521, strike, mallet, a knife, and two or three loosening wires, and small trowels, Figs. 522, 523. The moulds are made of fine sand and loam. Those used in the metropolis are obtained from Hampstead, and also from Lewisham. Common moulds are made of old damp sand, and they are generally poured while damp or *green*, but sometimes they are dried on the face. The old sand is much less adhesive than the new, and of a dark

Fig. 521.

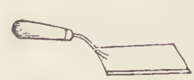


Fig. 522.

Fig. 523.

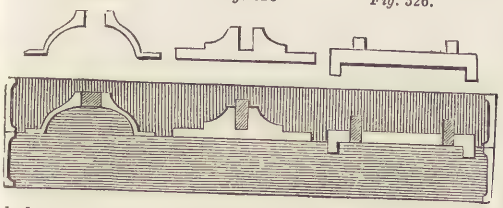
brown colour from the admixture of brick-dust, flour, charcoal-dust, &c., used in moulding. New sand and loam are occasionally added to the old stock, so that when moistened slightly, and pressed firmly in the hand, it may become moderately hard and compact. Red brick-dust is commonly used as *parting sand*, to prevent the separate portions of the damp sand in the two halves of the flask from adhering together. The face of the mould which receives the metal is generally

dusted with meal-dust or waste flour; or in large works with powdered chalk, wood, or tan-ashes. For the finest brass castings the moulds are faced with charcoal, rottenstone, or a mixture of the two, and dried over a dull fire of cork shavings, or smoked over pitch or black rosin lighted in an iron ladle. Gold and silver casters use a lighted link for facing their sand moulds: metallic moulds are sometimes smoked over a lamp; the object being in each case to deposit a fine layer of soot upon the moulds.

Where much loam is used, the moulds must be thoroughly dry before pouring, which is not generally necessary with ordinary sand moulds. The best castings are however obtained when the sand contains a good deal of loam and moisture, and has been closely rammed; but in such cases there is always a risk of accident, from the moist and impervious condition of the mould, and the resistance to the escape of air and vapour. The founder gets over this difficulty to a certain extent by using a little facing-sand, containing rather more loam, for the face of the green moulds. Iron-founder's sand is coarser, and therefore more porous than that of the brass-founder, and may be used in a moister state. As the castings contract considerably in cooling, it is also important in large and slight works, not to ram the face of the mould too strongly, or its strength may exceed that of the red-hot metal while in the act of contracting, and hence the casting would be rent or torn asunder from the restraint of the mould: whereas the metal ought to pull down the face of the sand instead of being itself injured.

When the objects to be cast contain one hole or several holes, they are said to be *cored*, and various methods are used for introducing internal moulds or cores, so as to intercept the metal at those parts. In pewterer's moulds pins are inserted for producing holes in the joints. In Figs. 524, 525, 526, the upper figures represent sections of the three models or casting patterns, and the lower figure represents the two

Fig. 524. *Fig.* 525 *Fig.* 526.



halves of the mould, the top half being shaded with perpendicular, the bottom with horizontal, and the cores with oblique lines, while the white open spaces show the hollows to be filled up by the fluid metal. When the cavity extends through the model, and exactly represents that which is required in the casting, as in Fig. 524, the work is said *to deliver its own core*. If the hole be sufficiently taper, it delivers its own core, as a continuation of the general mass of sand filling one side of the flask, but in many cases, the space in the model is rammed full of strong sand at first, and is then moulded as if to produce a plain solid casting. Before the mould is closed for pouring, the sand core is carefully pushed out of the pattern, and inserted in its proper place in the mould, which is indicated by one side of the core being scored with one or two deep marks, which produce similar marks in the mould. When the hole extends only partly through, as in Fig. 525, the hole of the pattern is filled with a solid plug of soft unburnt brick; the core is made long enough to project about as much as its own diameter, and the work is moulded as if to be cast with a solid pin instead of a hole. The core is then extracted and inserted into the hollow which it has itself formed in the flask. Patterns for iron-work are mostly made with *prints* instead of holes as in Fig. 526. The pattern maker places round or square pieces on one or both sides of the pattern, where the holes are required, and the founder has moulds for forming cores of corresponding diameters and sections, and in lengths of from 2 to 12 inches, short pieces of which are cut off as required.

Figs. 527, 528, represent the moulds for casting a pewter inkstand. They consist of four parts, the black portions representing the sections of the inkstand to be cast. The moulds consist each of a top piece or cap *t*, a bottom or core *b*, and two sides or cottles *s s*. In Fig. 528, one side is removed in order

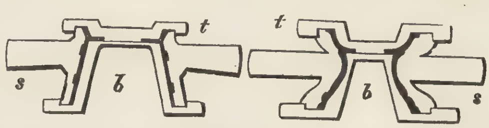


Fig. 527.

to expose the casting, and the top piece *t* is supposed to be sawn through to make the whole more distinct.

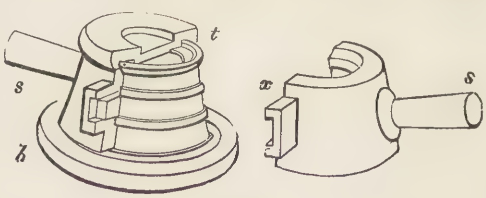


Fig. 528.

The top and bottom parts have each a rebate like the lid of a snuff-box, which embraces the external edges of the two side pieces *s s*, and the latter divide as in a bullet mould, exactly upon the diametrical line of the inkstand, which in a circular object is the largest part. In this way the positions of the parts are strictly maintained. When the mould has been put together, laid upon its side, and filled through *x* the ingate or *tedge*, it is allowed to stand a minute or two. The top *t* is then knocked off with a mallet; the mould is then held in the hand, and the centre part knocked out of the casting by the edge. The two sides are then pulled asunder by their handles, and the casting is removed from the one in which it happens to stick fast; but it requires cautious handling not to break it. The face of the mould is slightly anointed with red ochre and white of egg, to prevent the metal from adhering, and to give the works a better face. The first few castings are generally spoiled until the mould becomes warm.

In moulding patterns which are undercut, *false cores* are used, as in Fig. 530. It is evident that all the patterns in the mould, Fig. 529, can be extracted

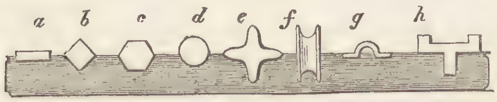


Fig. 529.

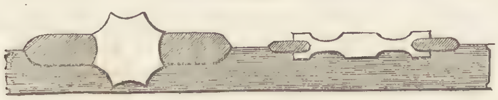


Fig. 530.

from each half of the mould, because none of them, when partly buried, extends beyond the line which separates the two parts of the flask: *a* and *b* could be laid in exactly upon the diagonal, or upon one flat side or partly embedded; *f g h* might be sunk more or less into the mould, their sides being perpendicular; but the patterns in Fig. 530 being undercut, the division of the mould into two parts only would be impracticable, and false cores or further subdivisions would be required in the manner shown in the figure.

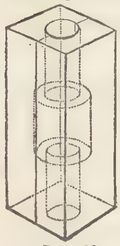


Fig. 531.

Many works require core-boxes to be made expressly for them, as in Fig. 531, where the dotted line shows an enlargement in the centre for coring a hole of that particular section. *c, d,* Fig. 532, represent the two halves of a brass or lead core-box used in casting the stop-cock; *a* represents the core after its removal from the part *c*, in which it is also figured. In *b*, the model from which the object is moulded, the shaded parts represent the projections, or *core-prints*, which imprint within the mould the places where the extremities of the core, *a*, are supported when placed therein.

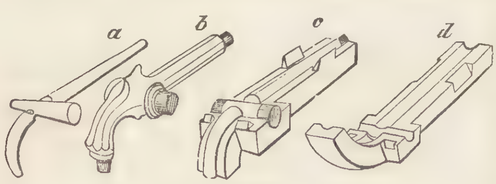


Fig. 532.

In the casting of figures, such as busts, animals, branches, foliage, &c., much skill is required. The originals are generally solid, but the moulds are divided into many parts. The complexity of such moulds may be judged of from works in plaster of Paris, which are sometimes sold before the seams of the mould have been removed. In all figured works approaching to the circular or elliptical section, the mould must be divided into at least three parts, except under very favourable circumstances. In the human figure and quadrupeds, the four limbs and the trunk require at least three parts each, and often many more. Piece after piece of the mould is successively produced, each piece embracing so much of the figure as in no part to require any core to overhang the line in which it is withdrawn. "The side of the mould in which the figure is partly embedded is first dusted with charcoal, and then the first core is very carefully rammed into the nook, and pared down to the new line of division. The green or wet sand-core is then dusted, and the second core is made, and afterwards dusted, when the moulder proceeds with the third core, and so on; each being carefully adapted to its neighbour, and withdrawn, to see that all is right, before the succeeding core is proceeded with. The relative positions of the cores amongst themselves are readily maintained and recognised by the irregularity of their forms, as in a child's dissected map, only making a notch or two here and there, which are faithfully copied in the succeeding piece. It is frequently necessary to thrust two or more broken needles through the green cores in the neighbouring parts to connect them together, in imitation of the pins in the flasks. All the parts of the mould are dried in an oven, and the facings are smoked over a cork fire; the perfection of the casting is augmented by pouring whilst the mould is still slightly warm, as otherwise on cooling it has an increased affinity for damp; but the mould when hot is more or less filled with the aqueous vapour, which is equally prejudicial.

"When a figure such as a bust is required to be cast hollow from a solid model, it is first moulded exactly as above. The core is now produced as follows:—At the foot of the bust a large space, nearly equal in length and bulk to the bust, is cut away in the sand, to serve for fixing the core in the mould, or for the *balance*, as it is called, as the core cannot be propped up at both ends. The entire hollow, that is, for the bust and the balance, is filled with a composition of about one part of plaster of Paris, and two of sand or fine brick-dust, mixed with a little water, and poured in fluid, a few wires being placed amidst the same for additional support. The mould is now taken to pieces to extract the core, which is then dried, thoroughly burned, and allowed to cool slowly, (which the founder calls *annealing*, from a similar method being employed in annealing or softening the metals, glass, &c. [See ANNEALING.]) The core is then returned to the mould to see that it has not become distorted. If needful, the filling around the balance is made good to suit the reduced magnitude of the core, which is then so far pared away as to leave room for the thickness of the metal. This is frequently regulated by boring holes at many parts of the core with a stop-drill, having a collar to prevent its penetrating beyond the determined depth. The surface of the core is now cut down to the bottom of the holes as uniformly as possible. When the mould has been faced, dried and smoked, &c., the whole is put together for pouring, for which purpose the figure is inverted, and filled from the pedestal. Equestrian and other figures are sometimes cast in two, three or more pieces, and joined together by solder, screws, or wires; but in all such works, the aim of the founder is to leave little or nothing for the finisher or chaser to do."[1]

Small animals, insects, parts of vegetables, &c.,

(1) Holtzapffel, "Mechanical Manipulation."

may be cast by the following contrivance. The objects are fixed in the centre of a small box by means of a few threads attached to any convenient parts, one or two wires being added to make air-holes and ingates for the metal. A small quantity of river silt or mud, carefully washed, is first thrown in and spread around the object by swinging the box about; and when partly dry, successive but coarser coats are thrown in, so as ultimately to fill the box. When it has become thoroughly dry, the wires are drawn out, and the mould is then burnt, so as to reduce the object to ashes, and when every particle of the model has been blown out, the mould is ready to be filled with metal.

This method has been improved on by Mr. Henry Dircks, who has found that by making his model in wax and then surrounding it with plaster-of-Paris, or other sufficiently plastic or hardening mould, the application of heat will cause the wax to be absorbed by the plaster, leaving the plaster cast quite sharp, pure and unsullied, having no waxed or oily appearance even where the wax was fully $\frac{1}{16}$th of an inch thick.—The plan is as follows:—Sheets of wax are cut and formed into any required shape, as usual in making wax flowers, &c., or in some cases the wax itself may be moulded or shaped to any particular form; and when the whole is arranged and put together, on a board covered with wax, air vents are formed by attaching the ends of waxed threads to the wax foundation, and the other ends to the loftiest points in the object, most suitable for the purpose. It must be remembered that the plaster mould will have to be turned upside down, and that when dry and warm from a suitable drying oven, the lower ends of all these threads will be uppermost and can be withdrawn, having shrunk from the loss of wax; which substance will also have been absorbed by every part of the mould, or where thick and in quantity may partly be run out. By using stearine and resin, with perhaps a little Burgundy pitch, a cheap substitute for wax is obtained. In forming wreaths, &c., as no colouring is required, the artist has only to attend to form, dimensions, and general arrangement. The copper castings obtained by this improvement, may be coated with the precious metals by means of electrotyping.[1]

A method of producing plates for printing copies of ferns, sea-weed, &c., has been invented by Dr. Branson of Sheffield, and is thus performed. A piece of gutta percha, free from blemish, and of the size of the plate required, is placed in boiling water: when thoroughly softened it is taken out and laid flat upon a smooth metal plate, and immediately dusted over with the finest bronze powder used for printing gold letters. The object of this is threefold; to dry the surface, to render the surface more smooth, and to prevent adhesion. A frond of fern, algæ, or similar flat vegetable form is then neatly laid out upon the bronze surface and covered with a polished metal plate, either of copper or of German silver: the whole is then subjected to an amount of pressure sufficient to imbed the upper plate in the gutta percha. When the gutta percha is cold, the metal plate is removed and the fern gently withdrawn from its bed. From the beautiful impression of the fern left in the gutta percha a cast in brass may be readily taken. As soon as the surface of the brass cast has been burnished, (of course carefully avoiding the impression,) it is ready for the copper-plate printer. If the printer skilfully mixes the ink to the tint of the fern, a print is obtained scarcely to be distinguished from the plant itself. The novelty of the process consists in causing the plant, so to speak, to engrave itself, and also in the substitution of a cheap casting in brass for an expensive copper-plate engraving. Electrotype plates may be deposited on the bronzed gutta percha, and a similar result obtained, but the brass casting answers equally well, and has the advantage of being more durable, cheaper, and expeditious.[2]

(1) Communication to the Athenæum, No. 1212.

The process of moulding in sand is similar whether the castings be brass or iron; but the large size of many iron castings gives rise to certain differences in detail. In most cases the iron-founder moulds and casts his works horizontally, with the flasks lying on the ground. In the largest works the lower part of the flask is omitted, such pieces being moulded in the sand which forms the floor of the foundry, in which case the position of the upper flask is denoted by driving iron stakes into the earth in contact with the internal angles of the *lugs* or projecting slips of the flasks. As the sand would fall out of large flasks when lifted up, a number of cross bars containing S-shaped hooks are inserted, and both bars and hooks are wetted with thick clay-water. Some flasks require the strength of two or several men to lift them, for which purpose iron handles are made to project from the sides of the flask. Very heavy flasks are lifted by means of a crane.

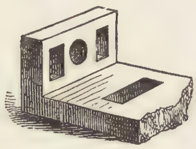
The sand of the iron-founder, as already noticed, is coarser than that of the brass-founder. The parting sand is the burned sand which is scraped off the castings; the facing sand is sometimes equal parts very fine coal dust and charcoal dust, with the addition in some cases of old or new sand, or a little road-drift. All these substances get mingled with the sand of the floor, and lessen its binding quality. This is remedied by the addition of new sand, or by using more moisture. Before extracting the patterns, the founder sometimes wets the edges of the sand with a sponge with a nail tied to it, to direct the water in a fine stream. For heavy works, a watering-pot is used.

The flasks are poured through a hole in the upper half, formed by placing a wooden runner-stick in the top part while it is being rammed full of sand, and a small channel is afterwards cut sideways into the mould. In some cases, a single casting requires two, three, or more runners; as where a great weight of metal is required, or where the casting is large but slight, as in trellis-work, because, in such cases, the metal might cool before the mould is full, if introduced only at one runner.

The iron-founder adopts all the methods of coring

(2) Communication to the Athenæum, No. 1208.

used by the brass-founder, and others which are not much used in brass-works, such as lateral holes in the parts of the castings buried beneath the general surface of the mould. The following example, from Mr. Holtzapffel's work, will illustrate this. Fig. 533 represents the finished casting; Fig. 534 the model of the same; Fig. 536 the appearance of the bottom



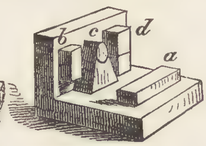
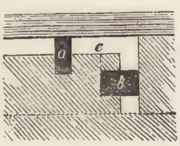


Fig. 533. *Fig.* 534.

flask or drag, when the pattern is first removed, and Fig. 535 the flask and cores, when closed ready for pouring. The moulds are inverted, and the same letters refer to similar parts of each figure. The core-print *a* would deliver from the sand, and leave the cavity at *a*, Fig. 536, to be afterwards filled by the core, shown black in Fig. 535, just the



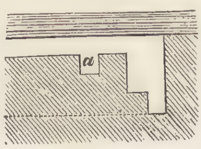


Fig. 535. *Fig.* 536.

same as explained in Fig. 526. But the core-print *b*, Fig. 534, which may be compared with the black stud *b*, Fig. 535, would tear away the sand above it in withdrawing the pattern; and therefore the print is made to extend to the neighbouring face of the pattern or the parting line, as at *e*, Fig. 535. This being the case, the pattern would leave the space denoted by Fig. 535; the core is put down sideways to the bottom of the recess, and extends entirely across the same; the small open space above is made good with the general surface, as shown by the shaded lines in Fig. 535, and this filling in at the same time fixes the core precisely where directed by the print *d*, which latter has a mark to denote to the moulder where the core is to end. The circular hole requires the core-print shown at *c*, Fig. 534, and the cores themselves are made in core-boxes, as before explained in the case of Fig. 531.

Fig. 537 represents the model and core-print from

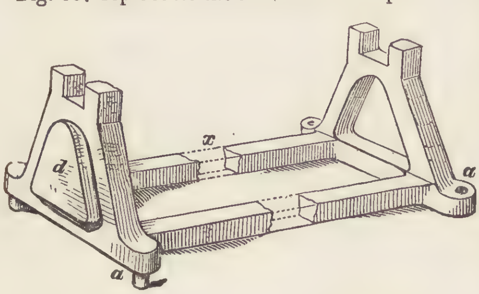


Fig. 537. *Fig.* 538.

which the finished casting, Fig. 538, may be made, from a solid pattern in a two-part flask: it would be inverted, and the parting would be made upon the line *x*. The print for the holes *a a* would be placed in the top flask, and those for the great apertures or panels *d* would be made in a core-box of the express form, and as thick as the pattern and core-print measured together. The core would be deposited edgewise into the core-print, and the upper corners of the mould would be made good, as explained in Fig. 535.

The iron-founder makes frequent use of flasks which divide into three or four parts, for the purpose of increasing the depth of the contained space. It is also sometimes necessary to make the casting in some respects different from the patterns. If, for example, the pattern be too long, or it is desirable to obliterate some parts temporarily, the mould is made of the full size and *stopped off*, additional sand being worked into the mould by means of a trowel and a piece of wood, to represent the imagined termination of the pattern. If, on the contrary, the casting is to be longer than the pattern, the additional piece is frequently cut off the mould with a trowel, &c. Some common works, such as plates, gratings, parts of ordinary stoves, &c., are made to *written* measures, without patterns, in which case a few parallel slips of wood represent the margin of the casting, and these are arranged upon a flat body of sand, which is modelled almost entirely by hand.

As iron castings contract in cooling, at the rate of about the 95th to the 98th of their length, or nearly 1 per cent., it is necessary to make the patterns somewhat larger than the intended castings. This allowance is made by employing a *contraction rule*, which is made like a surveyor's rod, but one-eighth of an inch longer in each foot than ordinary standard measure. In this way, in measuring out the pattern, the increased dimensions are given without entailing the trouble of calculation. If, however, an *iron* pattern is to be made from a wooden pattern, so as to serve for the permanent foundry pattern, a *double* contraction-rule is employed for making the wooden pattern: in this rule there is a quarter of an inch in excess in each foot.

"To lessen the distortion of castings, from the unequal contraction in the cooling, it is important that the models should be nearly symmetrical. For example, bars or rods of all the sections in Fig. 529 may be expected to remain straight: perhaps *g* is in the most danger; but if the lower fins of *e* and *h* were removed, their flat surfaces, then exposed to the sand, would become rounding or convex in length, from the contraction of the upper rib being unopposed by a similar piece on the other side. Bars and beams, the sections of which resemble the letter **I**, are of the most favourable kind for general permanence, and also for strength. Large panels may be cut out from their central ribs, to diminish their weight, without materially reducing their stability. They are very much used, not only in building, but also in the framing of machinery, which is in a great measure based upon the same rules. It is also of great importance, especially in castings of large size, that the *thickness* of the metal should be nearly alike through-

out, so that it may cool at all parts in about the same time. Should it happen that one part is set or rigid while another is semi-fluid, or in the act of crystallizing, there is great risk either of the one part being altogether torn from another and producing fracture, or, should the disturbing force be insufficient to break the casting, it may strain the metal nearly to its limit of tenacity or elasticity, so that a force far below that which the casting should properly bear may break it in pieces." This irregular contraction is partly prevented by uncovering the thick parts of the casting, or by cooling them by throwing on water from watering-pots.

As wood or metal patterns are very expensive, especially when the number of castings of the particular pattern is but few, this costly, and in some respects uncertain, method of casting is avoided, where it is practicable, by a simple and ingenious application of the art of turning, called *loam-moulding*. In casting a steam-cylinder, for example, the following method is adopted, and will be understood by referring to the figures. Fig. 539 is the entire section of the

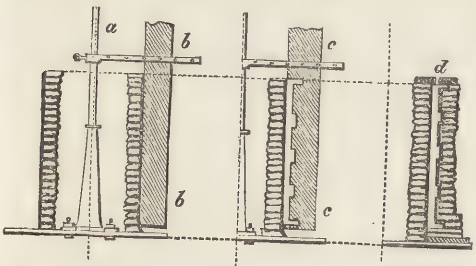
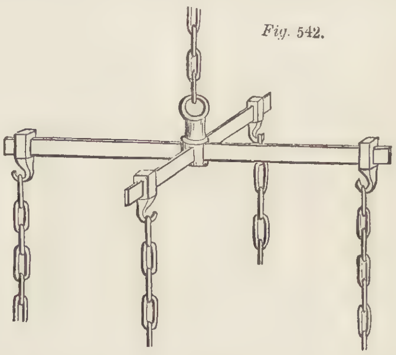


Fig. 539. *Fig. 540.* *Fig. 541.*

first stage; Figs. 540 and 541 are the half sections of the second and third stages, preparatory to burying the mould in the pit in which it is to be filled. The inner part of the loam mould is called the core, in small works, and the *nowel* in large: the outer part is the *case* or *cope*. Each part is built upon an iron loam-plate, or a ring rough on the face, and with four ears by which it may be lifted. Sometimes the mould is erected on four shallow pedestals of bricks, for the convenience of making a fire beneath it, to dry the loam. It may also be made upon a low truck, upon which it can be wheeled to the loam-stove, heated to 300° or 400°. A vertical axis *a* is mounted in two holes in the truck, or in a pedestal or socket erected thereon: or it may pass through a hole in the loam-plate, or in any bearing attached to the roof, &c. The first step is to fix on the spindle, by means of clutches or binding-screws, the templet *b b*, at the distance of the radius of the cylinder. An inner cylinder of brickwork is then built up, plastered with soft loam, (shaded black in the figures,) and scraped into the cylindrical form by the radius-board being moved round on its axis. When the surface is smooth, it is thoroughly dried, then covered with blackwash, and again dried. The charcoal-dust in the blackwash serves as a parting, to prevent the succeeding portions of the loam mould from adhering to the first. The templet *c c*, Fig. 540, cut exactly to the external form of the cylinder, is next attached to the axis, at the distance from the core required for the thickness of the metal. Additional loam is thrown on to form the thickness, which is carefully smoothed: the templet and spindle are then dismounted, and the thickness (represented white) is also dried and blackwashed. The ring for the outer case or cope is now laid down, and its position is denoted by fixed studs or by marks, and the brickwork shown in Fig. 541 is built up of bricks and loam, with an inner facing of loam, worked accurately to the turned thickness. The new work on the cope being thoroughly dried, is lifted off carefully by means of the crane and a cross-beam with 4 chains, Fig. 542. This process drags off the thickness, which

Fig. 542.



usually breaks, and any remaining pieces are carefully picked out of the cope: both parts of the mould are then repaired, and again blackened and dried. The mould is next put together in a pit sunk in the floor of the foundry, and the two iron plates are screwed together, the surrounding space being rammed hard, to prevent the mould from bursting open; but the inner part is left in a loose state, for the escape of air, &c. The top edges of the mould are covered over with a *loam-cake*, previously dried, or a ring, 3 or 4 inches thick, perforated with holes, as at *d*, Fig. 541, for the entry of the metal and the escape of the air.

The large cylinders of the Cornish pumping engines, of 80, 90, and 95 inches bore, and 12 or 14 feet long, and the blowing cylinders of blast furnaces, sometimes 105 inches bore, are made without using the thickness. The case or cope is built up in the pit and turned inside with a radius bar, and the core is erected on a plate on the floor and turned outside to a gage: when dried, it is lowered into the other by a crane. They are cast about a foot longer than is required, to make the top edge sound, and this additional length is cut off before boring. To enable the mould to resist the pressure of the column of fluid metal, (equal at the bottom to nearly 60lbs. per square inch,) the core is strengthened by diametrical iron bars entering a little way into the brick-work. The outer cylinder is surrounded by iron rings piled one on the other and made tight by ramming in sand, and stays are placed in all directions from the rings to the sides of the pit.

Large pans and other circular works are moulded in the same way as cylinders, except that circular templets are used. The cores of water-pipes are turned upon an iron tube pierced full of holes, which

is placed horizontally across two iron tressels with notches, and is kept in rotation by a winch handle at the end: a shaper board or scraper is fixed parallel with the axis. This arrangement is called a *founder's lathe.* The perforated tube is first wound round with haybands, then covered with loam, and the core is turned, dried, and blackwashed: the thickness is next laid on and blackwashed, after which the tube to be cast is moulded in sand. The thickness is then removed from the core, and the core is inserted in the mould, and supported therein by the two points at the extremities, and by *grains,* or two little plates of sheet-iron connected by a long central wire, the lengths of which may be seen by the bosses on the pipe, the metal being purposely made thicker to prevent the chance of leaking at those parts. In some cases, however, where pipes are cast in large quantities, they are moulded from wooden patterns in halves, so that it is only necessary to turn the core. The moulds for crooked pipes and branches are also frequently made in halves.

Many large works in brass are also moulded in loam. In some ornamental works, wax is employed for the thickness, and this is melted out before pouring the metal. Large bells are turned by means of wooden templets edged with metal, and shaped to the inner and outer contour of the core and thickness. The inscription and ornaments are either impressed within the cope, the clay of which is partially softened for the purpose, or the ornaments moulded in wax and fixed on the clay thickness before making the cope. In completing the apertures where the spindle passed, a dissected wooden pattern of the central stem and of the six *cannons* or ears by which the bell is slung is attached: these parts are moulded in soft loam, and the whole being dried and the iron ring for the clapper inserted, the whole is ready for the pouring pit. The heaviest bells are moulded within the pit.

Brass guns are moulded in loam, in the following manner:—A taper rod of wood much longer than the gun is wound round with soft rope, upon which the loam is put for making the rough casting model of the gun, which is turned to a templet, and the work is executed over a long fire to dry it as it proceeds. The model when dry is covered with a shell of loam about 3 inches thick, secured by iron bands, which is also dried. The taper bar is then driven out from its small end, the coil of rope is also pulled out, as well as every piece of the clay model. The parts for the cascabel and trunnions are worked separately on wooden models, and are then attached to the shell. Ornamental figures are modelled in wax and fixed on the clay mould before the shell is formed, and are afterwards melted out before casting. Six, eight, or more of these loam cases or shells are sunk perpendicularly into a pit at the mouth of the furnace, and the earth is carefully rammed round them; a vertical runner is made to each mould, to enter either at the bottom or not higher than the trunnion: the runners all terminate in the bottom of a long trough, at the further end of which is a square hole to receive the surplus metal. "In casting brass guns, tapping the furnace is rather a ceremony, and certainly an imposing sight: the middle and the end of the trough are each stopped by a shovel or gate held across the same; and the runners are stopped by long iron rods, there being a man to each. When all is pronounced to be *ready,* the stopper of the furnace is driven inwards with a long heavy bar, swung horizontally by two or three men, and the metal quickly fills the trough; on the word of command, "Number 1, draw," the metal flows into the first mould, and fills it quickly but quietly from the bottom; the mould being open at the top, no air can be accidentally enclosed. Numbers 2, 3, and 4 are successively ordered to draw. The first shovel is then removed from the great channel, and now the guns 5 to 8 or 10, as the case may be, are similarly poured and filled to the level of the trough; after which the last shovel is withdrawn, and the residue of the metal is allowed to run into the square bed or pit prepared for it. The flow of metal from the furnace is regulated by the tapping bar, the end of which is taper, and is thrust more or less into the mouth of the furnace as required: the trough and runners are thus kept entirely full, which is an important point in most cases of pouring, as it prevents a current of air being carried down by the metal. Large bells are poured much in the same manner, except that the runners are at the top, and the metal runs from the great channel through smaller ones to each sunk mould, the stoppers for which are successively drawn. For quantities of brass intermediate between the charge of an ordinary crucible, and such as require the reverberatory furnace, the large ladles or shanks of the iron-founder are used; the contents of 4 or 6 crucibles being poured into the shank as quickly as possible, and thence in one stream into the mould."

The furnace used for melting the iron for casting, is a blast or *cupola* furnace, although the cupola or dome leading to the chimney, from which it probably derives its name, is frequently omitted At the basement is a pedestal of brick-work 20 or 30 inches high, on which is erected a cast-iron cylinder from 5 to 8 feet high, and from 30 to 40 inches diameter: this is furnished with a lining of road-drift and other badly conducting substances, which contract its internal diameter to 18 or 24 inches. It is open at the top for the escape of flame, &c., and for the admission of the charge of pig-iron, waste or old metal, coke and lime, in proper proportions. The lime, which acts as a flux, is sometimes provided in the shape of chalk and oyster shells. The back of the furnace is provided with holes, one above the other, for the blast, which is urged by bellows. As the fluid metal collects at the bottom of the furnace, the blast pipe is removed to a higher hole and the lower one is stopped with sand. The front aperture, by which the melted metal is drawn off, is made sufficiently large to allow the fuel, slag, &c., to be rapidly raked out, as the intense heat renders this operation an arduous one. This opening is closed by a *guard-plate* fixed on by staples

attached to the iron case of the furnace: in the centre of this plate is the tapping hole, which is closed during the melting with sand well rammed in.

For large castings several of these furnaces are worked side by side: but a single cupola has been made to contain upwards of 12 tons of melted iron.

The proportioning of the charge for the iron furnace requires much judgment: it always consists of two, and often of six kinds of new pig-iron mixed together, to which new iron and a small proportion of old cast-iron is usually added. For sound castings with a smooth face, as for ornamental works, the soft kinds of iron containing most carbon are used: these are more fusible and flow easily. In castings for machinery, the object is to obtain a strong, sound and tough iron. Between the extremes of 3 parts pig-iron to one of old, or 3 parts of old to 1 of pig-iron, various qualities may be selected; but this is a point which depends so much on the experience of the founder, that very little can be safely written on the subject.

When everything is ready for casting, the hole near the bottom of the cupola is tapped, and the contents let out into ladles, or, in large works, into channels leading directly to the moulds. One man will carry from 50 to 70 lbs. in a hand-ladle; or 3 to 5 men will carry from 2 to 4 cwt. in a double hand-ladle or *shank:* larger quantities, amounting to from 3 to 6 tons, are carried in the crane-ladle. These ladles are all coated with a thin layer of loam, and every time they are used are brushed over with black-wash and carefully dried. The hand-ladle has a handle 3 or 4 feet long, with a *crutch* or cross-piece at the end. The shank has a single handle on one side, and a handle with two branches on the other, measuring together 6 or 8 feet: the tilting is managed by the man or 2 men at the double handle. The crane-ladle is carried from the furnace to the mould, by the motions of the crane. The *bail* or handle is fixed by a bolt or guard, to prevent the ladle being overset, until it has reached its destination. Two long handles with forked branches are fitted by their square sockets upon the swivels or pivots of the crane-ladle, and secured by transverse keys; the guard is then removed, and then 2 men at the ladle, 2 others at the crane, and 1 to skim the dross from the lip of the ladle, are sufficient to manage 2 or 3 tons and upwards of fluid-iron. "When cast-iron is very hot the metal scintillates most beautifully, far more vividly than a mass of wrought-iron raised above the welding heat: as the metal cools the sparks become intermittent, and at last the metal is entirely quiet, excepting a multitude of lines vibrating in all directions, as if the surface were covered with thousands of wire-worms in great activity: this effect lessens until the metal solidifies. The softest iron shows most of this play of lines, and is said to *break* the best. The pouring of very large objects in open moulds, such as plates, beams, girders, &c. is a very beautiful and grand sight. The metal is led from the furnace, through a gutter lined with sand, into a large trough or sow, the end of which is closed with a shuttle: when the sow is full the shuttle is raised: this allows the metal to flow very quickly into the mould, but enables it to be kept back, should

Fig. 543. POURING.

it be unnecessarily hot. The castings made in open moulds are generally covered up with sand as soon as the metal is set."

The larger number of castings are in the horizontal position, but cylinders, pipes, shafts, &c., and works which are required to be particularly round are cast vertically. In this case all the precautions before explained, for giving the mould sufficient strength to resist the pressure of the fluid metal, must be adopted, but as soon as the metal is set this resistance must be removed from the inner surface, in order that the cylinder may shrink in cooling without restraint. Accordingly, a few hours after the casting all the diametrical iron-stays are knocked away by a vertical weight or monkey, and men descend by iron ladders into the cylinder to break down the brick core; but the heat is so intense, that they cannot remain above a minute or so at a time. The precaution is however quite necessary to prevent fracture, and even in small castings of hollow objects, it is desirable to break down the cores to prevent them from scoring or breaking.

When the castings are removed from the mould, the runners are broken off, and the loose sand scraped off with iron shovels, wire brushes, &c., and the seams are smoothed off with chisels and files. The skin or crust of castings made in sand moulds, is generally harder than that of loam castings. In some cases, as in the teeth of wheels, it is desirable to retain this hard sand crust on account of its greater durability. When it is to be removed, it is desirable to pickle the works in dilute sulphuric acid, in a trough lined with lead, or to sprinkle the acid over them, and in a few days a thin crust is formed, which may be washed off with water, aided by slight friction. For pickling brass or gun-metal, dilute nitric acid is used.

The celebrated black iron trinkets commonly called Berlin ware, are successful examples of good castings on a small scale. This manufacture originated at the

time of the commencement of the final struggle between Prussia and France under Napoleon. The country, impoverished by long and unsuccessful wars, was enabled to struggle with her oppressor chiefly by the patriotism of her sons, who yielded their services, and of her daughters, who sent their jewels and trinkets to the royal treasury. Those who made this sacrifice received in return rings, crosses, and other ornaments in cast-iron, which bore the inscription, *Ich gab Gold um Eisen,* " I gave gold for iron," and to the present day these articles are valued as heirlooms in the families of the donors. The foundry is at Berlin, and strangers are admitted to witness the operations. The castings are not confined to trinkets; busts, statuettes, bas-reliefs, &c. are cast with great delicacy and fineness of impression, as well as minute filagree ornaments. Such is the fineness and delicacy of the separate arabesques, rosettes, medallions, &c., of which the larger ornaments are composed, that it requires nearly 10,000 of them to make up a pound weight. The price increases in proportion to the fineness, and taking the price of grey iron from which these ornaments are made at 6*s.* per cwt., the value of the material is increased 1,100 times in the coarser articles, and 9,827 times in the finest. The excellence of these castings is said to be due both to the quality of the iron, and to the care bestowed on the moulds, which are formed of a very fine sand mixed with a small portion of clay. Professor Ehrenberg says that the iron employed is made from a bog-iron ore, and that the sand is a kind of tripoli also containing iron: both are entirely constituted of various kinds of animalcules, several of which are found both in the fossil and recent states in the neighbourhood of Berlin.

One of the most delicate and difficult operations connected with casting is the formation of specula for reflecting telescopes. This subject has of late years received some important improvements at the hands of the present noble President of the Royal Society, the details of which are so exceedingly interesting in a mechanical point of view, that we propose to give a tolerably full abstract of them.

In the year 1840, Lord Oxmantown (now Earl Rosse) communicated to the Royal Society of London "an account of experiments on the Reflecting Telescope," the results of which were, "that specula can be made to act effectively, cast of the finest speculum metal, in separate portions, retained in their positions by an alloy of zinc and copper, as easily wrought as common brass, and that they can be executed in this manner of any required size; that castings of the finest speculum metal can be executed of large dimensions, perfect, and not very liable to break; that machinery can be employed with the greatest advantage in grinding and polishing specula; that to obtain the finest polish, it is not necessary that the speculum should become warm, but that any temperature may be fixed upon and preserved uniform during the whole process; and that large specula can be polished as accurately as small ones, and be supported so as to be secured from flexure."

To avoid the brittleness of the best speculum metal, it had hitherto been found necessary as the dimensions were increased to use an increased proportion of copper, so that the alloy was inferior in brilliancy, yellower, and much more liable to tarnish. In polishing large surfaces there were great and peculiar difficulties, all the defects having a tendency to augment rapidly with the size, and proportionately to impair the defining power.

Tin and copper, the materials employed by Newton in the first reflecting telescope, are preferable to any other; the best proportions being 4 atoms of copper to 1 of tin, or 126.4 copper to 58.9 of tin. This alloy, as well as every other speculum metal examined by the author, is porous, and the porosity can be detected with a simple Coddington's microscope.

The refined copper as it is procured from the merchant, and the best block tin are the materials. The difficulties experienced by Herschel and others in safely casting and polishing a very large speculum were proposed by Lord Rosse to be got rid of by uniting several castings into one reflecting surface, and as the best means of effecting that, to solder them upon an alloy of 1 zinc and 2.75 copper, which expands and contracts in the same proportion as speculum metal. To test this a bar was cast of speculum metal, 15 inches long and 1¼ inch square. Similar bars ¾ inch thick were cast of the alloys to be tried, containing a little more or less zinc than the proportions here given. A piece of brass consisting of 2.75 copper to 1 zinc was also cast and soldered to the bar of speculum metal, Fig. 544, where A B is

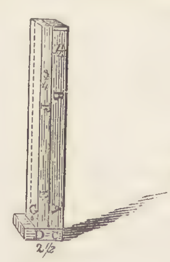


Fig. 544.

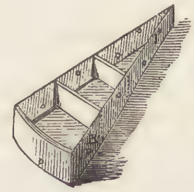


Fig. 545.

speculum metal, C D brass, and E F the bar of alloy, with a small excavation in the lower end fitted by grinding, so as to rest steadily on the hemispherical disk G. A thin slip of brass was also soldered at the upper end of the bar of speculum metal, and the two bars made to fit neatly there, so that when brought together, a very fine line could be drawn across them with scarcely any troublesome parallax at the joint; the whole was then immersed almost to the top in a tin vessel of water of the temperature of the atmosphere, and that vessel placed in another much larger, also containing water. Pieces of ice were then dropped into the outer vessel, so that the temperature of the whole was evenly and gradually brought down to nearly 32°, and a straight line as fine as possible was then drawn across both bars, and examined with a microscope to ascertain that it was perfect. The temperature was then gradually raised by pouring hot water into the outer vessel, to nearly 212°, and the line was again examined with a

microscope, and when the alloy had been made by mixing 2.74 copper with 1 of zinc, and the loss in melting amounted to $\frac{1}{180}$th of the whole, the continuity of the line was not broken in that range of temperature; according, however, as the proportion of the zinc was more or less, the expansion of the brass bar was greater or less than that of speculum metal.

Speculum metal and brass cannot be soldered together by the ordinary methods, except on a very small scale. But they may be soldered by first fitting the brass and speculum metal nicely together by fitting or grinding. The brass is then to be tinned and suffered to cool. Scrape the surface of the speculum metal lightly all over with a sharp chisel; then place the two surfaces in contact, and a slight pressure may be applied after the fusion of the tin, and continued until it is again solid. The temperature should then be gradually raised till the tin melts; and then, but not till then, resin is applied in fusion, and also a little melted tin. If resin or tin be applied in the solid state, owing to their rapid absorption of heat in becoming fluid, they will crack the speculum metal. The surfaces may be slightly separated, so as to ascertain that the speculum metal is tinned all over, which will be the case when the temperature reaches 400°. The whole must then be suffered to cool gradually.

In casting the alloy of zinc and copper some precautions are necessary to prevent so much of the zinc being volatilized, and thus producing speculum metal of varying and uncertain composition. Charcoal in fine powder must be spread over the surface of the metal in the crucible in a layer 2 inches thick, and occasionally renewed by throwing it in, folded up in paper. With this precaution the loss will be about $\frac{1}{180}$th, and almost exactly the same each casting.

The proportions of zinc and copper having been determined, the brass-work was first cast. The figures will show how the materials were disposed of. Fig. 545 represents one-eighth part of the whole seen

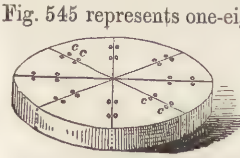


Fig. 546.

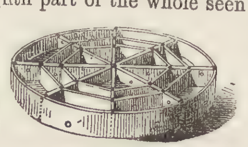


Fig. 547.

in the reverse, a single casting. Fig. 547, the whole speculum also seen in the reverse; and Fig. 546 seen on the opposite side, previous to the soldering on of

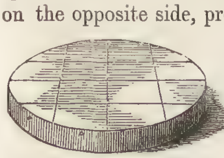


Fig. 548.

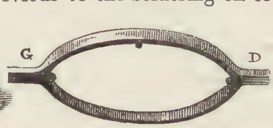


Fig. 549.

the plates of speculum metal; Fig. 548, the speculum complete, faced with 16 plates of speculum metal. The whole depth of the brass-work was $5\frac{1}{2}$ inches, and weighed about 450 lbs. The sides I B, Fig. 545, were made square and true, and then tinned, and the whole bolted together with iron bolts. The temperature was then raised till the tin was in fusion, and the bolts tightened to the utmost, so as to make close joints. In this state the speculum was turned, plated with speculum metal and polished. A flexure was, however, observed in this speculum, and it was supposed that the solder was not everywhere perfect. The plates of speculum metal were therefore taken off, and the joints secured by bedding the whole mass of brass-work in casting-sand; over it there were about 3 inches of sand. The sand was then removed from the centre, so as to expose a circular surface about $1\frac{1}{2}$ inch diameter, and about 45 lbs. of very hot melted brass, in the same proportions as the brass speculum, were poured upon it in a continuous stream from a height of about 10 inches; the sand having been so arranged that after the melted brass had reached the depth of 2 inches, the remainder continued to flow off. The melted brass soon fused the cold metal, and perfectly united with it at the place where it was poured. This was repeated in 34 different places, marked by dots in the figures. It was also tried in the places marked *c c*, but failed. When the redundant brass had been removed with a saw, and the surface made smooth, a slight hair crack was perceptible at the boundary of the fused metal, proceeding no doubt from expansion and contraction after the brass had ceased to be fluid, but before it had become ductile. This process is used by the brass-founder in stopping holes in defective castings; he calls it *burning*. To secure the joint at *c c* holes about $1\frac{1}{2}$ inch diameter were bored completely through at *c*, and the intermediate brass chiselled out. They were then filled with melted brass, which was easily done by imbedding the whole in sand; clearing the sand completely out of the spaces, and pouring the brass into each through a hole in a flat surface of sand packed in a small flask; when the brass cooled, the contraction was sufficient to draw the joint firmly together. As any further yielding in the joints was now judged to be impossible, the speculum was again placed on the lathe and turned to a radius of 54 feet, and new plates of speculum metal prepared for it.

Although none of these plates exceeded 9 inches square, much difficulty was experienced in casting them. When cast in sand they were seldom free from flaws, and although cooled very slowly were extremely brittle, sometimes flying in pieces the moment they were touched, and generally breaking in attempting to heat them for soldering. As the broken pieces of these plates did not fit each other, the metal had evidently been in a state of tension, owing to the edges of the plates becoming solid sooner than the centre. If it were possible to abstract the heat rapidly and equally from the lower surface of a fluid disk of speculum metal, so that it should solidify from the bottom upwards in thin laminæ, the surface being the last to solidify, a perfect casting would be obtained; for the particles in that case being deposited in such a way as to fill up the interstices, there would be no flaws; but the temperature being uniform in a horizontal direction, and in the vertical varying in regular gradation from the lower surface to the upper, there would be no strain.

This adjustment of temperature was tried in two ways; the one by cooling the lower surface of a mould containing the liquid speculum metal, while the heat of the upper remained undiminished; the other by constructing the mould itself, so that the lower surface should absorb the heat rapidly, and the upper retain it. Both were tried; the first by making the mould of cast-iron in which the metal was fused, and then exposing its lower surface to the action of a jet of cold water. The result was favourable, but the mould frequently cracked and spoiled the casting. By the second plan the bottom of the mould was made of iron and the sides of sand: when an iron plate was used, bubbles of air were often entangled between it and the speculum metal, producing cavities which had to be ground out: the iron disk was therefore replaced by one made of pieces of hoop-iron, placed side by side with their edges up, tightly packed in an iron frame; the edges were brought to a smooth surface of the proper curve either by the file or lathe. A porous metallic surface was thus formed, through which the air could pass freely. This plan was so successful, that of 16 plates cast for the three-feet speculum, not one was defective. The disk of hoop-iron must be as thick as the speculum to be cast upon it, so as to cool with sufficient rapidity: it requires to be warm (212°), so that no moisture be deposited on it from the sand. The metal should enter the mould by the side almost instantaneously. The temperature of the metal is best ascertained by stirring it with a wooden pole occasionally after it has become fluid; when the carbon of the pole reduces the oxide on the surface of the metal, and renders it brilliant, like mercury, the heat is sufficient. When the metal has become solid in the ingate or hole through which it enters the mould, the plate is to be removed quickly to an oven heated a little below redness, to remain till cold, which where the plates are 9 inches in diameter, should be 3 or 4 days at least.

The metal which had filled the ingates having been separated from the plates by a file, they were fitted to the brass speculum by grinding each separately by hand upon it till brought to the same curve. The surface of the brass speculum was then scraped and tinned, and when cold all the resin was removed by washing it with turpentine and then with soap and water. The lower surfaces of the plates which fitted the brass speculum were scraped with broad flat chisels of hard steel, and then arranged in their places on the brass speculum placed in an oven arranged like a sand-bath, so as to be heated entirely by hot air. In about 8 hours the tin on the speculum was fused, and then melted resin was poured in between the plates; fused tin was also afterwards applied in the same manner, and the plates moved a little backwards and forwards. As soon as from the aspect of the edges of the plates it was certain that the tin was acting on the speculum metal, the fire was almost all withdrawn, and the temperature not suffered to rise. The joints of the plates were now made straight, and kept open about $\frac{1}{20}$ inch by chips of wood: the whole was then suffered to cool gradually, and in five days it was ready to be ground.

The perfect union of the plates with the brass speculum, depends upon the fact that if a plate of speculum metal, scraped as directed, be laid upon a clean surface of tinned brass, and the temperature raised a little beyond the fusing point of tin, and then melted resin and tin applied, the plate of speculum metal will be tinned all over and the union be perfect. But if the resin be applied at the beginning of the process, and therefore exposed for hours to an increasing temperature, the resin will become decomposed and prevent the success of the operation.

Perfect plates of speculum metal of moderate dimensions having been cast, a trial was made on a larger scale, and a perfect disk of fine speculum metal 20 inches in diameter was obtained, and recently, so large a disk as 3 feet was cast perfect and finished without accident. The disk was about $3\frac{3}{4}$ inches thick, and weighed about 13 cwt. The metal for it was fused in two cast-iron crucibles. It is curious that iron crucibles cast in the usual way with the mouth down are generally defective, and the fused speculum metal will escape through minute pores in the crucible not visible externally, just as mercury passes through the sap vessels of wood. But when crucibles are cast with the mouth up there is no such defect. Lord Rosse cast one which held 15 cwt., in which the speculum metal was made; but as two crucibles of half the size were more manageable with less machinery, they were used in casting the speculum: they were raised from the furnaces by proper tackling, and placed in iron swing frames, so contrived that each crucible of metal could be thrown almost instantaneously into the mould. The fuel used is wood or peat, which is less injurious than coke upon the crucibles. The mould was made in the same manner as in casting the plates, differing from it merely in shape and dimensions: it was what founders call an open one. The disk of hoop-iron was made circular, $3\frac{1}{2}$ feet in diameter, $3\frac{1}{2}$ inches thick, and turned upon a lathe to a radius of 54 feet. The speculum was cast with a groove round the edge, so that it might be securely embraced by a circular clamp tightened upon it with screw-bolts, to which the proper tackling could be hooked when it was required to move it. When the metal had become solid, but was still red-hot, a strong hoop somewhat larger than the diameter of the speculum was placed upon it; to this hoop a chain from a windlass passing through the annealing oven had been previously attached, and by the action of the windlass the speculum was drawn into the hot oven, and every opening closed: in about a fortnight it was cool, and was found to be free from blemish.

On comparing the speculum thus formed at a single casting, with that formed by combining a number of small castings, no appreciable difference was found as to defining power; both were free from flexure in the different positions of the instrument, and defined equally well when polished with equal success. With a single lens of $\frac{1}{4}$ inch focus,

giving a power of about 1,300, they have both shown satisfactorily the dots on the dial plate of a watch more distinctly than a very good refractor with a much lower power.

Before the speculum is polished, it is worked to a spherical figure by *grinding*, a process in which the mutual attrition of the speculum, and a mass of nearly equal size of some hard substance, eventually produces a figure nearly spherical, notwithstanding the irregularities of the surfaces of either or both at the commencement of the operation. But although the accuracy usually attained is so great, that mechanical means fail to detect any deviation from the proper figure, yet by optical means, in fact by trial in a telescope, the defects are at once apparent, and among a variety of specula, examples may be found of every grade of defining power, from the speculum which is almost perfect to that which does not define at all. These differences arise from variations in the extent or relative velocities of the motions by which the necessary friction is produced; alterations of temperature; or some accidental pressure during the process. It was always supposed that specula could not be polished successfully except by the hand; but so long back as 1828, Earl Rosse published a sketch of a machine for grinding and polishing specula. This machine, enlarged so as to be capable of working a speculum 3 feet diameter, and otherwise improved, was used on the present and many other occasions, and in working large surfaces a degree of precision is attained which by the hand is impossible. The machine in its present state is shown in Fig. 550, where S is a shaft connected with a steam-engine, (one horse-power is sufficient;) E an eccentric, adjustable by a screw-bolt to give any length of stroke from 0 to 18 inches; $\mathfrak{s}$ a joint; G a guide; C a cistern of water in which the speculum revolves; E′ another eccentric, adjustable like the first from 0 to 18 inches. The bar *g* E′ passes through a slit, and therefore the pin at E′ necessarily turns on its axis in the same time as the eccentric; S P is the speculum in its box, immersed in water to within 1 inch of its surface, and P the polisher, which is of cast-iron and weighs about $2\frac{1}{2}$ cwt.; D is a disc of wood connected with the polisher by strings hooked to it in 6 places, each two-thirds of the radius from the centre. At D is a swivel and hook, to which a rope is attached connecting the whole with the lever L, so that the polisher presses upon the speculum with a force equal to the difference between its own weight and that of the counterpoise W. For a speculum 3 feet diameter, the counterpoise is made 10lbs. lighter than the polisher. The bar *g* E′ fits the polisher nicely but not tightly, so that the polisher turns freely round, usually about once for every 15 or 20 revolutions of the speculum, and it is prevented by 4 guards from accidentally touching the speculum, and from pressing upon the polisher, by the two guides through which its extremities pass. In Fig. 549 this bar is shown on a larger scale. The wheel E makes, when polishing a 3-feet speculum, 16 revolutions per minute; to polish a smaller speculum the velocity is increased by changing the pulley on the shaft S. The machine is in a room at the bottom of a high tower, and doors can be opened in the successive floors, so that a dial-plate placed perpendicularly over the speculum can be examined at any

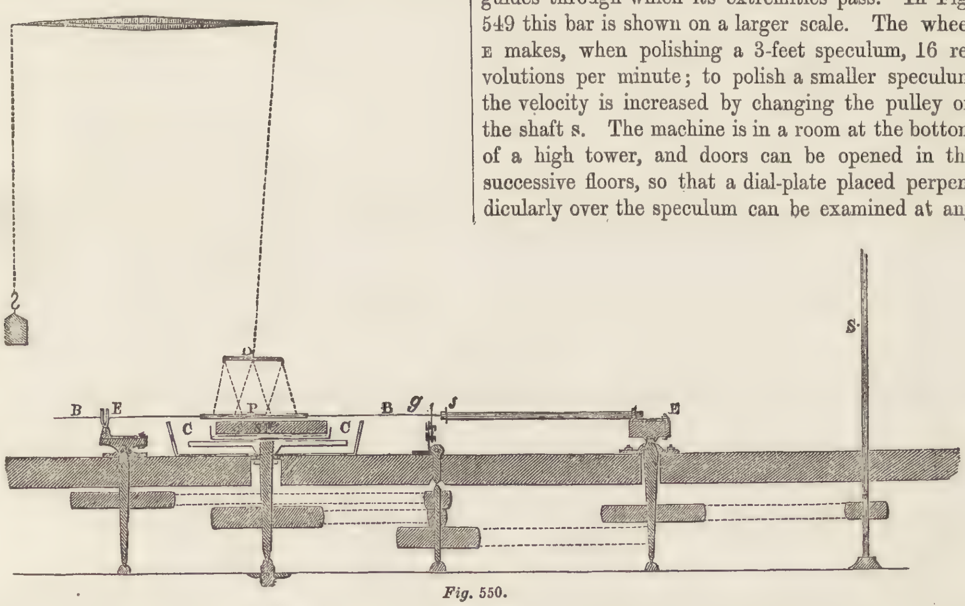


Fig. 550.

moment. The dial-plate is attached to a mast, so as to be much higher than the tower and about 90 feet from the speculum; and a small flat metal eye-piece with its proper adjustments completes the arrangements for a Newtonian telescope. This simple contrivance greatly facilitated the progress of the experiments. All the motions of the machine were produced by bands 3 inches wide instead of cog-wheels, the former being preferred, because if any part of the machinery should become fast the band falls off or breaks, and no mischief is done.

The first serious difficulty in polishing specula of large size was, that when the layer of pitch used as a bed for the polishing powder was thin, as it must be to produce a good figure, however accurately it fitted the speculum at first it soon ceased to do so, and the polishing did not proceed properly. During the operation of polishing, the abraded matter, mixed

with the polishing powder, is in part taken up by the pitch, but not equally over the whole surface. As pitch is not sensibly elastic with a moderate pressure, wherever most is taken up there the surface will be most prominent, and the figure of the polisher destroyed unless the pitch can spread laterally. It occurred to his Lordship that by grooving the layer of pitch provision might be made for its lateral expansion, without increasing the thickness of the layer, which is most objectionable. The experiment was tried by reducing the thickness of pitch one half, and making furrows in it by means of a hot iron quite down to the metallic plate; the furrows were 2 inches apart, and there were 2 sets at right angles to each other. The result was that the defining power of the speculum was immediately much improved. But the difficulty of keeping the furrows open, of preserving the figure of the polisher, and of reducing the thickness of the pitch to a minimum, which was a great object, still existed; but all defects were remedied by dividing the iron disc itself instead of the pitch: this was accordingly done by turning

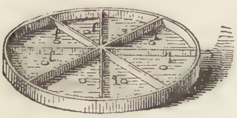


Fig. 551.

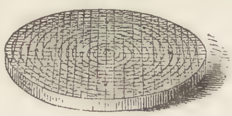


Fig. 552.

circular grooves in it $\frac{3}{8}$ inch deep and $\frac{1}{4}$ inch wide, and also grooves at right angles $1\frac{1}{4}$ inch apart, $\frac{1}{4}$ inch wide, and $\frac{1}{2}$ inch deep. Fig. 552. The speculum was truly ground with the polisher first, and then the layer of pitch or resinous composition applied, the grooves remaining empty. The improvement which followed this simple device was decided; for the divided 3-feet speculum defined better with a power of 1,200 than it had done before with a power of 300. The two conditions necessary to success, are that the polisher should fit the speculum exactly during the whole process, and that the resinous surface in contact with the speculum should be as hard as possible consistent with its admitting the polishing powder to imbed itself in it. A mixture of common resin and turpentine was found preferable to pitch, on account of the gritty particles so common in the latter. It is desirable also to use the resinous composition of two different degrees of hardness, so as to form two very thin strata, the outer one being the harder. Thus the surface in contact with the speculum can be made as hard as necessary, while the thin subjacent layer of soft resin expands laterally so as to preserve the figure of the polisher. The composition is prepared by melting common resin, and when nearly boiling adding about $\frac{1}{5}$ of its weight of spirit of turpentine: when the mixture has been incorporated by stirring, a piece of cold iron is immersed in it, and then placed for some minutes in a vessel of water at the temperature of 55°; if then a moderate pressure of the nail makes a decided impression without splintering, it is of a proper hardness for the first layer on the polisher, and only requires to be strained through canvass. For the second layer it is mixed with $\frac{1}{4}$ of wheat flour, which by increasing its tenacity and diminishing its adhesiveness prevents the common fault so much complained of, viz. the separation of minute particles of pitch from the polisher. It is to be boiled till the water of the flour has been expelled, and the mixture becomes clear, and the boiling further continued till some of the turpentine has been driven off, and the mixture has become so hard that at 55° a very strong pressure of the nail makes but a slight impression. An equal weight of resin is then added to it, when it will be hard enough to produce a very true surface, and yet soft enough to allow the particles of polishing powder to become imbedded. When the resinous mixture is remelted, the vessel is suspended to the beam of a scale, and the heat applied so gradually as not to drive off any of the turpentine, which is immediately perceptible by the disturbance of the equilibrium. To apply the resin the polisher is first heated to about 180°, and the soft mixture laid on with a large flat brush to about the thickness of $\frac{1}{80}$th or $\frac{1}{25}$th of an inch. It is then suffered to cool to about 100°, and the hard mixture is applied in the same way, and to about the same thickness. When the temperature has sunk to 80°, the polisher is placed on the speculum, previously covered with peroxide of iron and water, of about the consistence of thin cream. The speculum is made to revolve in a cistern of water, c Fig. 550, maintained at the constant temperature of 55°, and the hardness of the resinous composition is adjusted to suit this temperature as above explained. When the polisher is first applied at 80°, while the speculum is at 55°, there is no danger of fracture, because the layer of resin retards the transmission of heat; but in grinding, where there is no resin, such a difference would lead to the fracture of the speculum. In grinding the 3-feet speculum formed in separate pieces, the iron plate happened to have been washed with warm water, and though but little warmer than the speculum, the moment it was put on several of the plates cracked; these of course admitted of being replaced. Had it been the other speculum in one piece, it would of course have been destroyed.

The polishing powder must be prepared by precipitation with water of ammonia from a pure dilute solution of sulphate of iron. The precipitate is to be washed, pressed in a screw-press till nearly dry, and then exposed to a heat, which in the dark appears a dull low red. The sulphate of iron must be pure, the ammonia in excess, and the heat not greater than that indicated. The colour of the powder will be a bright crimson inclining to yellow.

We have thus abstracted from Earl Rosse's most interesting paper the principal mechanical details which he has found successful in the casting, grinding, and polishing of large specula. There are other details connected with the figure of the specula, the method of mounting them, and the astronomical results obtained from their use in telescopes, which do not belong to this article.

CASTOR, a brown viscid substance, secreted by

castors or beavers, and formerly much used in medicine in nervous and spasmodic diseases. At the present time not only are the virtues of this substance considered very equivocal; but the uncertain composition and quality of that offered for sale afford good reason for allowing it to fall into disuse.

CASTOR OIL. An oil obtained by boiling in water or by crushing in a press the seeds of the *Ricinus communis* or *Palma Christi*, an annual plant growing in tropical countries. This plant is extremely variable in size, has large vine-shaped leaves, green spikes of flowers, and rough capsules containing ovate shining black seeds spotted with grey. As cultivated in this country, the Palma Christi is an annual three or four feet high; in Sicily it is a woody and long-lived tree-shrub about the size of our common alder; in Spain and in different parts of India, it attains a larger size, and becomes a considerable tree. The seeds yield a pale fixed oil, nauseous and slightly acrid. When this oil is obtained by boiling, it is deeper coloured and more acrid, and also more liable to become rancid, but is also generally more active than the pale-coloured oil. Some of the oil now sold is absolutely without colour or taste, and appears to have undergone a decolouring process, but in this state it is frequently almost inactive; so that oil of a pale straw-colour having a slight degree of taste and smell is preferred.

Castor oil was formerly expressed with heat, but this and the mode of boiling the seeds in water is now seldom adopted; *cold-drawn* castor oil being the favourite form of this medicine. Some medical writers consider cold-drawn oil as more active than that obtained by boiling, while others affirm that the latter is more active than the former. This medicine is well known as a mild laxative, which can be safely employed in all cases except those in which it is dangerous to excite vomiting, an effect sometimes produced by it. Castor oil congeals at about 0°; exposed to air it gradually becomes rancid, and very thick and viscid; it dissolves in absolute alcohol and ether. Its sp. gr. is about .960. When treated with a little nitric acid, it is converted into a substance resembling hard butter.

CASTORS, small wheels attached to the legs of

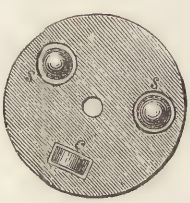


Fig. 553.

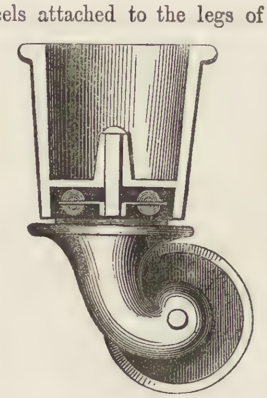


Fig. 554.

furniture, to allow of its being easily moved about. Harcourt's castors are shown in Fig. 554, the upper or socket part being in section. Round the central pin is fixed a guide-plate, so as to revolve with it. This plate contains circular holes, in each of which is a small sphere which rolls as it is carried round with the plate. Fig. 553 is a plan of the guide-plate, which may contain three or more apertures for the antifriction rollers; and these may be spherical as *s s* or cylindrical as *c*. The use of these antifriction rollers is to remove the strain and pressure on the central pin.

CATECHU. See Tannine—Leather.

CATENARY. The curve in which a perfectly flexible cord or chain (Latin *catena*, a chain) hangs when it is suspended by two points that are not in the same vertical line. "All catenaries are similar curves; that is to say, let there be any number of such curves formed by chains of different lengths, then each of them will be a picture, on a reduced or enlarged scale, of some portion of the longest." The properties of the catenary are of great importance from the general use of this curve in suspension bridges. "The curve, however, of a chain supporting the roadway of a bridge is not strictly a catenary. In the catenary the weight is supposed to be distributed so that each equal length sustains an equal portion of it. Now the weight of the roadway of a bridge is not so distributed on the chains. The suspending rods are, indeed, placed along it at equal distances from one another, but the lengths of the portions of the curve included between these are different; those about the lowest points of the chain only being equal to the included parts of the roadway, whilst those near the extremities are greater. Hence, therefore, the chains used in supporting the roadway of a bridge do not assume strictly the form of the catenary. Were the chain without weight, the pressure of the roadway upon it would, indeed, cause it to assume the form of the parabola. In reality it is a curve intermediate between the catenary and parabola, partaking of the properties of both."[1]

A catenarian curve is sometimes adopted for arches and vaults. A practical instance of the equilibrium of the catenary is mentioned by the writer of the article Bridge in the Encyclopædia Metropolitana. "A scientific gentleman of Birmingham having occasion for a close factory for the manufacture of the article called Roman vitriol, set out a piece of ground to be covered by a brick arch of considerable length, the chord of which was 18 or 20 feet, and its versed sine about 12. He suspended a chain against a wall, the points of suspension being equal to the chord of his intended arch, and its depth equal to its versed sine. From a line traced from the chain his carpenters made a centre, over which the bricklayers turned a single arch of 9 inches only in thickness, without spandrels or other external support, its extrados being a curve parallel to its intrados at a distance of only 9 inches. It is a perfectly sound and beautiful piece of construction. During an absence from home he desired another to be built like it. The self-sufficient workman varied the curve

(1) Moseley, "Mechanics applied to the Arts."

to give it more room in its haunches, or a more graceful curve, and on striking the centre it fell."

CATGUT, a name given (inappropriately as it would appear[1]) to cords made of the twisted intestines of the sheep. When the intestines are removed from the body of the animal, they are freed from feculent matter and adhering fat, and washed in a tub of water. The small ends of the intestines are then tied together, and placed on the edge of the tub, while the great bulk is left during two days to soak in the water, which is frequently changed. In this way the peritoneal and mucous membranes become loosened. The bundle of intestines is then laid upon a sloping board overhanging the tub, Fig. 555, and the man with a square steel edge scrapes the surface, and removes the external membrane in breadths of about half the circumference of the intestine. The French term this substance *filandre*, and the process *filer*. It cannot be

Fig. 555. SCRAPING.

removed by beginning at the large end. This filandre is used as thread to sew intestines, and also to make the cords of rackets and battledores. The scraped intestines are steeped during one night in clean water, and next day are again scraped with a rounded edge. This is called *curing*. The large ends of the intestines are cut off, salted, and stored in covered tubs for the purpose of being sold to the pork sausage-makers. The intestines are again steeped for a night in fresh water, and the next day are treated with an alkaline mixture formed by adding 4 ounces of potash, the same quantity of pearlash, to 3 or 4 gallons of water. The membranes are then distributed to a number of women, each of whom stands before two basins or pans containing the alkaline solution, Fig. 556 ; and each woman draws the intestines through an open brass thimble, pressing them against the edge for the purpose of smoothing and equalizing them. In this way the membranes are passed from one basin to the other several times. They are next sorted into different sizes, according to the purposes for which they are intended.

Fig. 556. PASSING THROUGH THE THIMBLE.

For making *whip-cord*, the intestines, prepared as above, are sewed together by means of the filandre, each junction being cut aslant, in order to make it smoother and stronger. A number of these cords are then put into a wooden frame, the two uprights

Fig. 557. TWISTING.

of which are furnished with a quantity of holes containing pegs for securing the ends of the gut, and for passing the lengths round. The spinner attaches the end of one of the cords to the hook of a little whirling apparatus, (similar to the *whirl* of the rope-maker, only smaller,) which he causes to rotate rapidly by turning a handle: this puts twist into the gut, and somewhat diminishes its length. He secures the twist by pegging the cord into the frame, and then proceeds to twist another cord. When all the cords have been treated in this way, and other frames of cords similarly twisted, they are all piled up horizontally in a small close chamber, lined with lead, where they are subjected to the action of the fumes of burning sulphur. The manufacturer calls this *bleaching;* the effect, however, is not to whiten the cord, for that is produced by previous manipulations in alkaline leys, &c.; the real effect seems to be to destroy any animal matter that might still be attached to the membrane, and occasion putrefactive fermentation. Certain it is that, without sulphuring,

(1) A writer in the Gentleman's Magazine for June 1818, speaking of the origin of the "Signs of Inns, &c." refers to the *Cat and Fiddle, Cat and Bagpipes,* and similar objects collocated without any apparent reason. He says:—"Between the Cat and Fiddle there may, indeed, appear some connexion, as the entrails of the one are supposed to furnish the strings of the other; or the sign might originate in the ambiguity of the word *Kit*, at once the abbreviation of *Kitten* and a *small violin*."

the cords are liable to an unpleasant odour, and even to become mouldy. After the sulphuring, the whip-cord may be dyed black with common ink, or red with red-ink, which the sulphurous acid changes to pink, or green with a green dye which the colour-maker sells for the purpose. The membrane takes the dye readily. The twist being completed, the cords are nicely smoothed, and are then placed for an hour or so in a hot room, where the heat, probably 180° or 200°, fixes and consolidates them: they are lastly cut off the frames and twisted up into coils for sale.

Hatters' cords for bowstrings, used in the curious operation of *bowing*, [see HAT,] are made of the longest and largest intestines of sheep, and after being properly cleaned and smoothed with the alkaline ley, they are twisted in lengths, 4, 6, 8, 10, or 12 together, according to the intended size of the cord, which is usually about 12 feet long. This cord must be free from lumps and knots, and when half dry it must be sulphured twice, and, after each operation, well stretched, twisted, and smoothed, and it is finally dried in a state of tension. The object of sulphuring cannot in this instance be to bleach, for colour is no object; some of these cords being dyed black, others a dingy red, and others left of their natural colour.

Clockmakers' cord must be very thin, strong, and durable, for which purpose it is made from very small intestines, or from intestines slit up in the direction of their length by a couple of razor-blades fitted into a ball of wood which serves as a guide. The wet gut, being drawn over the ball, is divided, and the two sections, properly directed by the workman, fall into a basin beneath. This operation is one of considerable delicacy, but when performed well, the gut is divided into strips of perfect regularity with great rapidity. A number of these strips are twisted together and treated as before.

The French prepare a very strong cord from the gut of the horse, ass, or mule, for driving machinery. The gut, having been scraped, is divided into four equal parts, by skilfully drawing it over a fixed knob containing four sharp edges, or two semicircular blades, arranged at right angles. 4, 6, or 8 of these strips are tied at the ends with packthread, then twisted together, and polished with dogskin.

The strings for *harps, guitars*, and the instruments of the *violin* family, require the best attention of the cat-gut maker. The first scraping is performed with great care. A little alum is added to the alkaline leys, which are made progressively stronger every day for four or five days, till the membranes are well bleached and swollen. They are then passed several times through the thimble, after which they are spun, and sulphured, and are lastly polished by friction between horse-hair cords, and dried in the hot room.

The Italians make much better musical strings than the English. Otto, in his "Treatise on the Violin," says:—"The best strings which have come under my observation are those from Milan, which are sold under the name of *Roman strings;* they are now to be had at almost every music-shop. I shall point out the signs by which the best strings may be distinguished, as there are some imitations of them manufactured at Neukirch, in Voigtland, in Bohemia, and in the Tyrol, which are sold for Italian. The Milanese strings are as clear and transparent as glass. The third string should be equally clear as the first. They must by no means feel smooth to the touch, for they are not ground or polished off by any process, as all other manufactured strings are. If a good string be held by one end in the finger and opened out, it will recoil to its former position like a watch-spring. Every string when stretched on the instrument should look like a thin strip of glass on the finger-board: those which are of a dull and opaque appearance are useless. The Milanese strings are also distinguished by each separate one being tied twice with red silk: which, however, the Neukirch string-makers have imitated. Their elasticity is after all the best criterion, as no other strings which I have tried have that strength and elasticity for which the Milanese are so much esteemed."

The chief fault of the English compared with the Italian strings is weakness; whence it is difficult to bring the smaller ones required for the higher notes to concert pitch, maintaining at the same time in their form and construction that tenuity or smallness of diameter which is required to produce a brilliant and clear tone. The frequent fracture of such strings is a source of constant inconvenience and expense.

"It is well known to physiologists that the membranes of lean animals are far more tough than those of animals that are fat or in high condition; and there is no reason to doubt that the superiority of the Italian strings arises from the state of the sheep in that country. In London, where no lean animals are slaughtered, and where, indeed, an extravagant and useless degree of fattening, at least for the purpose of food, is induced on sheep in particular, it is easy to comprehend why their membranes can never afford a material of the requisite tenacity. It is less easy to suggest an adequate remedy; but a knowledge of the general principle may at least serve the purpose of diminishing the evil and improving the manufacture, by inducing the manufacturers to choose in the market the offal of such carcases as appear least overwhelmed with exuberant fat. It is probable that such a manufacture might be advantageously established in those parts of the country where the fashion has not, as in London, led to the use of meat so far overfed; and it is equally likely that in the choice of sheep for this purpose, advantage would arise from using the Welsh, the Highland, or the South Down breeds, in preference to those which, like the Lincoln, are prone to excessive accumulations of fat. It is equally probable that sheep dying of some of the diseases accompanied by emaciation would be peculiarly adapted to this purpose." [1]

The engravings which illustrate this article were made from sketches taken at a cat-gut manufacturer's in Sharpe's Alley, London. The manufacturer per-

(1) Dr. MacCulloch, in the "Quarterly Journal of Science, &c." 1821.

mitted the Editor to inspect the various processes above described, but refused to answer any questions which were put to him, or to allow of a second visit. We have, however, corrected our sketch from the excellent article, BOYAUDERIE, contained in M. Laboulaye's "Dictionnaire des Arts et Manufactures," Paris, 1845; and have also obtained much additional information therefrom.

There is a considerable demand for untwisted gut on the part of the sausage-maker, the druggist, the confectioner, and all those trades where clean dry membrane is required. For these purposes, the intestines are prepared in the following manner:— 1. A length of gut is taken from the tub in which the fresh intestines are kept, and removed to a trough containing water. The small end of the gut is tied in a knot to a staple fixed to the end of a bar of wood rising up near the trough. The man then takes a length of a few feet in his left hand, and pulling it tight, scrapes it with a fleshing-knife, by which means he removes the peritoneal and fatty membranes from this portion. This being done, he unties the knot, and makes another near the place which separates the scraped from the unscraped portion; then, taking up another length, he scrapes as before. Any portion of the gut which is torn or rent, as often happens from the carelessness of the butcher, is cut off, and thrown aside. The fat which has been scraped off is washed and dried, and sold to the soap-manufacturer. 2. The scraped intestines are thrown into a vessel half-full of water. Taking up one of the ends, the man inserts his fingers into it, and presses his thumb on the outside: then with the other hand he draws the gut down, and dips it into the water, at the same time spreading his fingers to enlarge the opening. In this way, by advancing his fingers, drawing down the gut, and dipping into the water, the gut is quickly turned inside out. When a number of intestines have been thus prepared, they are tied together by the ends. 3. In this state they are left to ferment from 5 to 8 days, in winter, and from 2 to 3 in summer. The putrefactive process is known to be sufficiently advanced by the bursting of bubbles of gas on the surface of the water. In summer, the fermentation is liable to proceed too rapidly, in which case it is checked by throwing a glassful of vinegar into the tub. During this process, the putrid odour which is diffused all around is dreadful. 4. The mucous membrane, which has been loosened by this fermentation, can now be easily removed. The intestines are transferred to a tub two-thirds full of water, and a woman draws each gut between her hands, pressing it firmly against her nails, or against a blunt edge. This removes the mucous membrane; but a portion of the peritoneal membrane is still left, which is removed by a further process of putrefaction. 5. For this purpose, the intestines are thrown into tubs full of water, which is changed once or twice a-day, stirring them about each time. They are then left for two or three days before the water is removed. The water is at first in a state of ferment, and very putrid; an iridescent pellicle forms on its surface, and bubbles of gas frequently escape: the water at length becomes clearer. and the intestines are then taken out and blown. 6. This operation is performed by the men who scraped the guts: each man puts on a leather apron, and places his knife on the tub, so that its edge may be opposite to him, so as to be always ready when wanted. He holds in his mouth a hollow reed, about six inches long, which he inserts into one extremity of a gut, and distends it with air. He then withdraws the tube, and ties the end of the gut with thread: he then blows at the other end, which he secures in like manner. If the gut contain a small hole, it is discovered by passing the gut through water, with slight pressure; the air bubbling out shows where the hole is: this is made tight by pinching the membrane, and passing a ligature round it. If the gut is torn, it is tied above and below the rent. When the intestines are inflated, they are conveyed in osier baskets to the drying-ground. 7. The drying-ground is provided with long frames of wood, on which the blown membranes are spread, so as not to touch each other. If they have been properly cleaned, they will become perfectly dry in about two days; if not well cleaned, they scarcely become dry in five. In rainy weather they are put under shelter in sheds or lofts. They must also be protected from wind and dew and from the hot sun. 8. When dry, they are taken into a sort of damp cellar, where women cut off the ligatures, as also those portions of gut near the ligatures which have not been blown. The membranes are then pressed together to expel the air, and are, 9thly, made up into bundles, and left until sufficiently moist for sulphuring, or they may be made moist by sprinkling with water. 10. They are then hung up in loose bundles in a close room, and exposed for some hours to the fumes of ignited sulphur. Lastly, they are folded up in bundles, and packed in sacks, and are ready for sale.

The trade of the catgut and membrane manufacturer is peculiarly disgusting. M. Laboulaye says that the people who work at it always retain the filthy odour communicated by their occupation, even when they are dressed in their holiday clothes, and are enjoying themselves in their own rough way. It is not at all necessary that the disgusting putrefactive odours which accompany this trade should exist. M. Labarraque's *disinfecting liquid* (hypochlorite of soda) has been employed with distinguished success in all the preparatory processes, at a very slight increase of cost, entirely destroying the odour, improving the colour, and in no way injuring the strength of the membrane.

The gut skin used by the gold-beater is prepared from the cæcum of the ox. [See GOLD.] The method of preparing silkworm gut will be described under SILK.

CAULKING. See SHIP-BUILDING.

CAUSTIC, any chemical substance which corrodes the skin and flesh: potash is called *common caustic*, and nitrate of silver *lunar caustic*.

CAVIAR, a substance prepared in Russia, consisting of the salted roes of large fish. The best,

which is made from the roe of the sturgeon, caught in the Wolga, in the neighbourhood of Astrachan, appears to consist entirely of the eggs: it is packed in small kegs, but the inferior sort is made into the form of dry cakes. It is highly esteemed in Russia, and also forms an article of considerable export; 30,000 barrels having been exported from Astrachan in a single season. The manufacture consists in separating the roe from its membranes, then washing in vinegar or white wine, and drying by spreading it out on a board in the air. Salt is then well rubbed in, and it is next put in a bag and the liquor pressed out. It is then packed in kegs for sale. During the three annual seasons of fasting in Russia, the consumption of caviar is very great, as it is also in Italy during the fasts of the church. It is eaten on bread, with oil and lemon-juice or vinegar.

CEMENTATION. See STEEL.

CEMENTS. See LIME—MORTAR—STUCCO.

CENTRE. See BRIDGE.

CENTRE or CENTER, (Greek κέντρον, a sharp point.) In geometry generally, a point equidistant from the two extremities of a line, or from all similar points of the circumference or boundaries of a surface or solid.

Centre of gravity. That point through which the resultant of the weights of all parts of a body or system of bodies always passes; on which point the body or system would balance in every position. The following are rules for finding the centre of gravity in various figures and solids:—

Triangle. From the middle points of any two sides draw lines to the opposite angles: the intersection of these lines is the point sought. Or, from the middle point of either side draw a line to the opposite angle. The centre of gravity is in this line, at two-thirds of its length from the angle to which the line is drawn.

Parallelogram. The intersection of the two diagonals is the centre of gravity.

Trapezium. Divide it by a diagonal into two triangles; find the centre of gravity of each: then the centre of gravity of the whole is in the line joining these points. Call one of these triangles A B C, and its centre of gravity E. Then, area of whole trapezium : area of triangle A B C :: whole line between the two centres of gravity of triangles : distance of centre of gravity of trapezium from E.

Segment of circle. Divide the cube of half the chord, by three times the area of half the segment. This gives the distance of the centre of gravity from the centre of the circle.

Sector of circle. Multiply the chord by two-thirds of the radius, and divide by the arc. This gives the distance from the centre, as in the last.

Cube or parallelopipedon. At the intersection of any two diagonals.

Cylinder or prism. At the middle of the axis.

Cone or pyramid. In the axis of the solid, at a distance of $\frac{3}{4}$ths the axis from the point.

Generally any figure which is symmetrical about an axis, has its centre of gravity in that axis.

To find this point in a surface unsymmetrical:—Suspend it by a string from any point of its edge, and with a plumb-line mark on the surface the vertical passing through the point of suspension. Repeat this with any other point in its edge, and the intersection of the two lines will be the centre of gravity.

Centre of pressure—in hydrostatics. That point in a surface sustaining the pressure of a fluid, at which the whole pressure may be conceived to act, without altering the equilibrium of the surface, or to which a single force could be applied, to sustain the whole pressure of the fluid and keep the surface in equilibrium. The centre of pressure of a rectangular plane, (whatever be its inclination,) extending to the surface of a fluid, is in the middle of its width, and at a distance of two-thirds its depth from the surface.

The hinges of lock-gates, the hoops of vats, and all other contrivances by which the pressure of fluids is to be resisted, should have their places determined in relation to the position of the centre of pressure. For practical application, see HYDROSTATICS—INLAND NAVIGATION, &c.

Centre of oscillation. If a heavy mass be suspended by a thread or string, it can be made to swing to and fro as a pendulum, with a certain definite speed. Now, if all the parts of that mass could vibrate separately, each with the speed due to its distance from the point of suspension, those elements nearest this point would vibrate more quickly than the others which are more remote from it. But as, in fact, the whole mass must vibrate together, the nearer particles are retarded, and the more remote particles are accelerated, by their mutual conjunction into one mass. The whole mass, therefore, vibrates with a speed intermediate between one and the other. That point between the nearer and more remote elements, where the particles just cease to be accelerated and begin to be retarded, is the *centre of oscillation.* If the weight of the whole mass could be *compressed* into this one mathematical point, then this would continue to vibrate with the same speed as the mass before such compression. The length of a common pendulum is measured from the point of suspension to the centre of oscillation, and not to the end of the bob.

Centre of percussion. The centre of percussion is that point in a moving body, or system of bodies, through which the whole effective force of the motion of the body may be conceived to act, and to which point, therefore, if a single obstacle of sufficient strength were opposed, the whole body or system would be stopped, without any tendency to turn round or glance aside from that obstacle. In striking a cricket-ball, we know that there is one point in the bat, on which if the ball impinge no jar or shock will be given to the hand. But if the ball strike above or below this point, the hand is jarred, and even the bat may be broken. This point is the *centre of percussion.*

In a body revolving about a fixed axis or centre, the *centre of oscillation* is in the same point as the *centre of percussion.*

To find the distance of the centre of percussion or oscillation from the point of suspension:—

In a line, small parallelogram, or cylinder, suspended by one end, two-thirds of the axis.

In the cylinder suspended at one end, to two-thirds the square of the altitude add half the radius, and divide this sum by the altitude. If a sphere be suspended from any point outside its surface, square the distance from the point of suspension to the centre of the sphere; to this add two-fifths of the square of the radius, and divide the sum by the distance of the point of suspension from the centre of the sphere.

To find the centre of oscillation or percussion experimentally: suspend the body from the given point, so as to vibrate very freely, and make it oscillate in small arcs. Adjust the length of a thin cylindrical rod so that it may, when suspended freely by one end, oscillate at the same rate as the body to be observed. Two-thirds of the length of this rod will be the distance of the centre of oscillation or percussion of the body from its given point of suspension.

For practical applications see PENDULUM—TILT-HAMMER.

Centre of gyration, is a point in a body or system of bodies revolving about a fixed axis, such, that if the whole mass were compressed into that point, any given force would in a given time, cause that point to revolve with the same velocity that it would have given to the body or system of bodies. Hence, in investigations of the velocities which descending weights can be made to communicate to wheels or wheelwork, the calculations are made with respect to the centres of gyration of such wheels.

The distance of the centre of gyration from the axis of rotation is :—

In a circular wheel of uniform thickness, half the radius multiplied by 1.4142.

In a solid sphere revolving about a diameter, the radius multiplied by .6325.

In a circular ring revolving about the centre, the square root of half the sum of the squares of the radii of the outside and inside of the ring.

CERASINE. See GUM.

CERATE, from *cera* wax. A somewhat stiff unguent, made of oil, lard, and wax, with the occasional addition of a substance in powder.

CERINE. See WAX.

CERIUM, a rare metal, named after the planet *Ceres.* The interest which attaches to it is at present purely chemical.

CERUSE, one of the names of white-lead. See LEAD.

CHAIN. See SURVEYING.

CHAIN-CABLES. The greatest improvement that has been made of late years in mooring vessels, has been the introduction of the chain-cable, by Captain Brown of the West India merchant-service, who in 1811 first employed chain-cables in the ship Penelope, of 400 tons burden, of which he was captain. The first chain-cables were of twisted links: Mr. Brunton introduced straight links stayed in the middle with a cross-rod, and in 1828 Mr. Hawkes obtained a patent for constructing these chains with short rods of iron with swells or protuberances about one third of their length from each of their ends, so that when these ends are welded together, the slenderer parts are at the sides, and the thicker at the ends of the elliptic links.

The original cost of a chain-cable is not much more than that of a hempen one, while its durability is infinitely greater as well as the security which it affords, for it is exposed to none of the deteriorating causes which render a hempen cable so little trustworthy. "The alternate wetting and drying which saps the strength of a hempen cable, has no effect on one of iron. The friction against rocks, especially against coral, is often fatal to a hemp cable in a few minutes; but the same friction after weeks of hard use only slightly polishes a few links of the chain. In tropical countries, therefore, the introduction of chain-cables has increased the security of ships at anchor tenfold; but in every climate their advantage is immense. Nor does this advantage consist solely in their strength and durability, for they are managed with much more facility, occupy far less space, and are coiled away with little, or it may be said no trouble at all; for as they are hove in, they fall quietly to and adjust themselves in a box or case near the hatchway, from which they are drawn up when wanted with comparatively small labour. To those who remember the toil and trouble of 'forming a bend' in the cable tier, the wet and the dirt, and the noise made by the numbers of men required to coil it away, these advantages will not be considered as small ones." [1]

On the introduction of the chain cable, the inventor thought it necessary to give his cable a certain degree of elasticity, lest the ship, coming to her bearing on the chain suddenly, might carry it away. With this view, the links of the chain were twisted about half way round, so that when the strain took place, the links by yielding a little, or partly untwisting, might produce an effect somewhat similar to the natural elasticity of hemp. This provision was, however, not necessary, because the weight of the chain was found sufficient to check the impulse, and to act in the same way as elasticity in the hempen cable. Moreover, this twisting of the links tended to weaken them. Accordingly Mr. Brunton took out a patent for an iron cable, in which the iron for the links was not twisted. Each link was oval in form with a broad-headed stay in the middle (as in Fig. 558,) to prevent it from collapsing or shutting up under a heavy strain. Another advantage of this stay is that it prevents the different links from entering each other as they are liable to do in a common chain, thereby entangling the cable. The two shaded circles in this figure are portions of two adjoining links, in section.

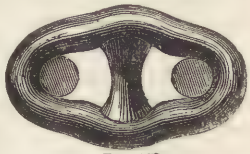


Fig. 558.

The link was further improved by Messrs Acraman of Bristol, who in 1820 took out a patent for the

(1) Encyclopædia Britannica, *Art.* Navigation.

same. The iron for the links was formed into cylindrical bars of varying diameter, with projections or swells so placed as to come exactly opposite to each other when the bar is turned into a link. (Fig. 559.) The extremities of the bar are scarfed so as to fold over each other a sufficient length, which gives the link in that part when shut or welded additional strength. If the projections are made sufficiently prominent to meet when the bar is turned into a link, they form by their union a very effectual stay, as in Fig. 560 *a*. But if the projections are not sufficiently raised to meet when such bar is turned into a link, the projections are indented or countersunk so as to form two cups of a round, oval, square, or other shape, and a uniting stay is then introduced, and closed in by pressure. The stays are of various lengths and shapes as required. By this contrivance any pressure or strain on the link has the effect of holding the stay tighter and closer in its proper position. A link with a stay of this description is shown in Fig. 560 *b*. A link with the projection not so much raised is shown in Fig. 560 *c*.

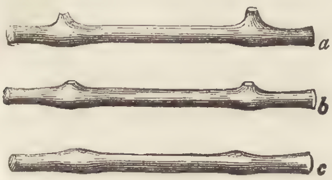


Fig. 559.

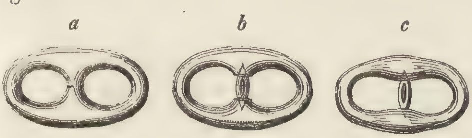


Fig 560.

The inventor says, that in these forms of link "it is obvious that there are no thin edges or angles in the stay liable to be chipped off, worn away, or injured by pressure or strain, which has in different ways been the case with all the stays hitherto made. Such accidents are completely avoided in the link Fig. 560 *a*, by its containing its strength and resistance purely within itself, and that in so compact a form as to prevent any injury short of an actual removal, forcing or crushing of the particles of the metal out of their places, which must, as is well known, require a very extraordinary power not at all likely to occur in the common use of the article. And in the links, Fig. 560 *b*, *c*, the same advantages exist in nearly an equal degree, as all pressure or strain from the sides will be made on a smooth stay of iron, opposing in all its parts an equal resistance over a considerable surface."[1]

In 1822, Mr. Sowerby patented a chain cable, a sufficient idea of which will be conveyed by Fig. 561. The opposite sides of each link are bent inwards as at *a*; the sides are held firmly together by a cross bar of malleable iron passing through a block of cast-iron *b*, which cross bar is welded to each side of the link; and for the purpose of preventing the links from entangling, there are small projections on the inner quarters opposite to each other, and next towards the middle of the link as at *c*.[2]

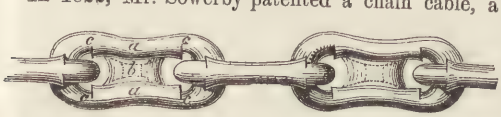


Fig. 561

In 1828, Mr. Hawks patented an invention for thickening the ends of the links at the points where the greatest friction, and consequently the greatest wear, takes place. The inventor states that chain cables, by reason of the continual friction of the ends of the links against each other, have a great tendency to wear away, so that having been in use a short time, the strength of the links is diminished. The improved links are formed from cylindrical bars produced either by rolling, swageing, or stamping, with projections or swells A A, Fig. 562, placed at such distances on the bar as to come exactly opposite each other when the bar is turned into a link, by which means the extremities of the links are made thicker than the sides. The extremities of the bar are scarfed at C D so as to fold over each other, and are welded at the sides of the link. No. 2 shows the bar bent or turned into a link ready to be joined or welded. No. 4 shows the finished link, and No. 3, the same with a stay in the centre.[3]

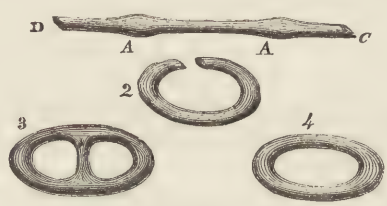


Fig. 562.

As a rope or a cable is no stronger than its weakest part, a single defective link would practically render the whole cable equally defective. The strength of every cable is therefore tried before it is issued, by a machine adapted for the purpose.[4]

As it is sometimes necessary to cut the hempen cable in order suddenly to release the ship, it was necessary to make some provision for severing the chain cable. This is done by means of a bolt and shackle at every fathom or two fathoms, so that by striking out this bolt, the cable is readily detached.

In the use of chain cables, the hawse-holes are fitted with strong cases or tubes of iron. Sir Thomas Hardy contrived a stopper by which the cable can be at any time prevented from running out, whatever be the strain upon it. This stopper consists of a large swan-necked bar of tough iron embracing the cable as it comes up the hatchway, having one of the ends of the curve fixed to the beams of the lower deck by means of a powerful bolt, whilst to the other end is attached a tackle, also worked on the lower deck, by

(1) Repertory of Arts, Manufactures, &c. vol. xl Second Series. London. 1822.

(2) Repertory of Arts, Manufactures, &c. vol. xliii.

(3) Repertory of Patent Inventions, &c. vol. xi. 1831.

(4) A notice of Capt. Brown's proving machine will be found in the article BRIDGE, p. 226 ante.

which this curved stopper can be drawn tight, and the chain pressed so firmly in its embrace against the angle of the hatchway, that however quickly it may be running out, or whatever strain may be brought on it, the cable is arrested almost immediately.

Another form of cable-stopper, invented by Mr. Batten, is shown in Fig. 563. The apparatus is

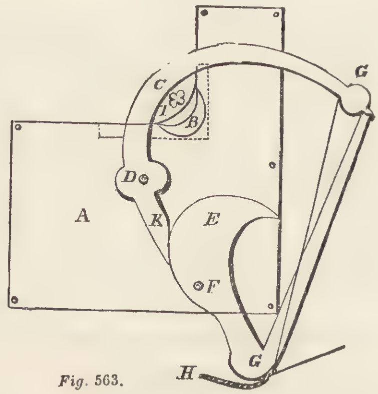


Fig. 563.

intended to be fixed under the hatchway of the deck. The whole is of wrought iron: A is an iron plate; B a thick boss of the same, over which the chain or cable I runs; C a lever playing upon a fulcrum D; E an eccentric lever moving upon its fulcrum F, and acting upon the second short lever K. The chain or cable I is nipped or stopped altogether by the extreme ends of each lever being compressed by means of a rope that passes through the pullies G G. In order to set the chain or cable free, the lever may be retracted by a short rope H fastened to the extremity of the lever E.

When a ship is at anchor the weight of the chain-cable is a great advantage, the strain being exerted on the cable rather than the ship, and this strain must be enormous to draw the cable into a straight line. Instances are related of ships enduring a violent storm of several days, during which 30 or 40 fathoms of their iron cables have been completely polished by contact with rocks and other rough materials. The great weight of these cables is, however, in one respect a disadvantage; for this being added to the weight of the anchor, is so great that they cannot be used in deep water without some modification, which usually consists in combining the hempen with the chain-cable, the anchor being shackled to the latter, and the hempen cable with the top metal link.

The use of chain-cables has been greatly promoted by the fact, that vessels provided with them can be insured on more favourable terms than those which do not possess these improved means of security.

CHAIN-SHOT. Two iron balls linked together by a chain 8 or 10 inches long. They are used in naval warfare, for the purpose chiefly of damaging the enemy's rigging.

CHAIN-WORK. See HOSIERY.

CHALK, one of the numerous forms of carbonate of lime. See LIME.

CHALYBEATE SPRINGS, mineral waters which contain *iron* in such quantity as to form one of their leading ingredients. The term is derived from the Latin *chalybs*, iron or steel. See MINERAL WATERS.

CHARCOAL. See CARBON.

CHART, a plane projection of some part of the sea, for the use of navigation. See MAP.

CHASING of METALS. The valuable property of malleability possessed by certain metals, admits of their being spread out into sheets: these sheets can be formed into useful and ornamental vessels, &c., by cutting, bending, joining, spinning at the lathe, &c., while the same property of malleability admits of their being raised and embossed by stamping, raising, snarling, chasing, &c. This curious and important subject will be considered under the article SHEET METAL, WORKS IN: but the reader who desires to study the subject in detail is referred to the first volume of Mr. Holtzapffel's work on Mechanical Manipulation.

CHEESE. The principal season for cheese-making is from May to September, and it is carried on in nearly every county of England, but there are particular districts which have acquired great repute for the cheese produced therein. The process is in nearly all cases the same. It is well known that milk, after the cream has been removed, will separate, as it becomes sour, into two parts, curd and whey. But this sort of curd would not answer the purpose of the cheese-maker; therefore, the natural process is imitated and hastened by mixing a small quantity of acid with the milk, which has the effect of curdling it without injuring its quality. The acid commonly used is rennet, a preparation of the gastric juice from the stomach of a sucking calf. Experience teaches the quantity of rennet necessary to curdle a certain quantity of milk, the milk being previously coloured with annotto, to the tint required for the description of cheese about to be made. When the curd has formed and is firm enough to be separated from the whey, the dairy-woman plunges her hands to the bottom of the cheese-tub, and with a small wooden disk stirs and breaks the curd, which process she afterwards completes with her hands, carefully breaking up every lump, and reducing the whole to fragments no larger than a hazel nut. This may also be done by the *curd-cutter*, Fig. 564, an oval hoop of copper, with a stem of round copper rod and a wooden handle. When the curd is thoroughly divided it sinks to the bottom of the tub, and the whey is then ladled off from it, and sent to the hog-tub, or set aside for whey-butter. Care is taken to press out all the whey from the curd by means of the lading dish and the hands, after which

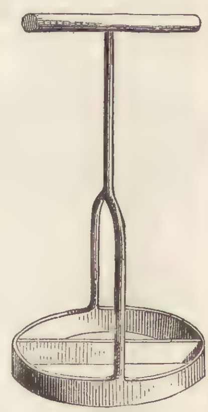


Fig. 564.

the curd is cut through in squares with a knife to allow any remaining whey to flow from it. The curd is now ready for the vat or mould in which it is to be shaped into a cheese. This is made of elm wood, as being least liable to burst with pressure; it is pierced with holes at the bottom, to allow the whey to escape, and has also a strong wooden cover. In filling the vat a cheese cloth is spread loosely over it, and the curd after further breaking up and squeezing, is pressed into the vat and piled up on the top in a rounded form. The ends of the cheese-cloth are then folded over, and the vat with its contents, placed in the cheese-press, where it receives a degree of pressure varying with the size of the cheese. Cheese presses are of several kinds, the simplest being merely a long beam, one end of which is frequently placed in a hole in the wall, while the other is loaded with weights, the cheese vat being placed between the two. Another form is a timber frame, within which is a large square stone capable of being raised and lowered over the vat at pleasure. A third is a cast-iron press, Fig. 565, or frame, with a perpendicular piston arranged to cover the sinker of the

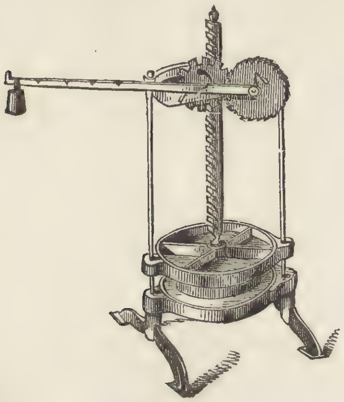


Fig. 565.

cheese-vat, and raised or lowered by a small pinion attached to a ratchet wheel and lever three feet long. The lever is grooved on the upper side to hold the ring of the weight for increasing or diminishing the power in proportion to the distance from the ratchet wheel. The pressure of this instrument can be made to equal about 20 tons, and its cost is about four-and-twenty shillings. The vat containing the cheese remains under pressure at first for about three hours; it is then taken out, the cheese removed and allowed to stand for an hour or two in a vessel of hot whey, for the purpose of hardening the outer coat: it is then wiped dry, left to cool, and then covered with a clean cloth and returned to the vat, which has also been wiped dry. Another three hours' pressure, and it is again taken out, but merely for the purpose of wrapping it in a dry cloth and returning it to the vat. This is continued twice a-day for two days, the cheese being turned each time in the vat: it is then finally removed from the press and carried in the vat to the salting tub. In all the above processes, the state of the cheese-cloths is of great importance: they are of coarse linen of an open texture, and are repeatedly washed and wrung out in boiling-water without soap. An abundance of clean dry cloths for wiping out dairy vessels after they are washed, is an indispensable item in the furniture of a dairy.

The cheese in its vat is next covered with brine in the salting-tub, and remains several days, being regularly turned each day. It is then removed from the vat to a salting-bench, where it stands for a week or ten days, being carefully rubbed with salt every day. If the cheese is large, a wooden hoop or a fillet of cloth is put round it to prevent it from cracking. When sufficiently salted it is removed to the drying-bench and thence to the cheese-room, where its future management consists chiefly of wipings and turnings, and regulations as to ventilation. In Cheshire cheese the salt is well mixed with the curd, and not merely rubbed on the outside.

This, which is the most celebrated English cheese, is made in quantities amounting to nearly 14,000 tons annually. The rich cheese called Stilton is made in Leicestershire: it is not sufficiently mellow for use, under two years old. Double and single Gloucester cheese is also well known. The former is made of the milk and cream, the latter of the milk and half the cream. Bath and York are famous for cream cheeses.

Good cheeses are produced in large quantities in Holland. In Gouda cheese, which is considered the best made in that country, muriatic acid is used instead of rennet. Hence it is never infested with mites. Parmesan cheese, from Parma, in Italy, is skim-milk cheese, owing its rich flavour simply to the fine herbage on the banks of the river Po. Swiss cheese, especially that of Gruyère, is pleasing to some tastes. It is flavoured with herbs. Our chief imports of cheese have hitherto been from Holland, but within the last few years a large quantity has been received from the United States. In 1847, this latter amounted to 109,322 cwts. The duties previous to 1842, were 10*s.* 6*d.* per cwt. on all descriptions of foreign cheese; but in that year, cheese from a British possession was admitted at 2*s.* 6*d.* per cwt. duty. In 1846 a further reduction took place, the foreign being admitted at 5*s.* per cwt., and that from British possessions at 1*s.* 6*d.* In 1849 the total imports of cheese were 379,648 cwts., the quantity entered for home consumption 390,978 cwts., and the revenue £97,686.

CHICORY, a root of the endive or dandelion family, used for mixing with coffee. It is cultivated largely in Germany, and is exported to this country from Hamburg in large quantities. It is also grown in Yorkshire, Lincolnshire, and Suffolk. The seed is sown in April, and the harvest is gathered in September. The roots are pulled up and washed: they are then cut across into pieces about the size of a walnut and dried at a kiln, by which means 4 or 5 tons are reduced to 1 ton. It thus arrives in London in a dried shrivelled up state, in pieces resembling the cross sections of a parsnip. It is of a whitish colour, almost tasteless, and very light

with respect to its bulk. To prepare it for use it is roasted in the same manner as coffee, [see COFFEE,] which changes it into a blackish brown colour. It is then spread out in shallow boxes or coolers, and when cold it is picked by hand for the purpose of separating portions of wood or stone that may by accident have got in. The roasted and sorted chicory is next ground by the action of two massive granite-edge runners, Fig. 566, to which motion is given by a vertical axis, to which they are connected by means of two short horizontal axes projecting from the vertical one. The granite runners thus moving upon their horizontal axis by their contact with the bed, pass constantly round by the motion of the vertical axis and crush the material which is thrown in. The bed-stone is also of granite 2 feet thick, and weighing

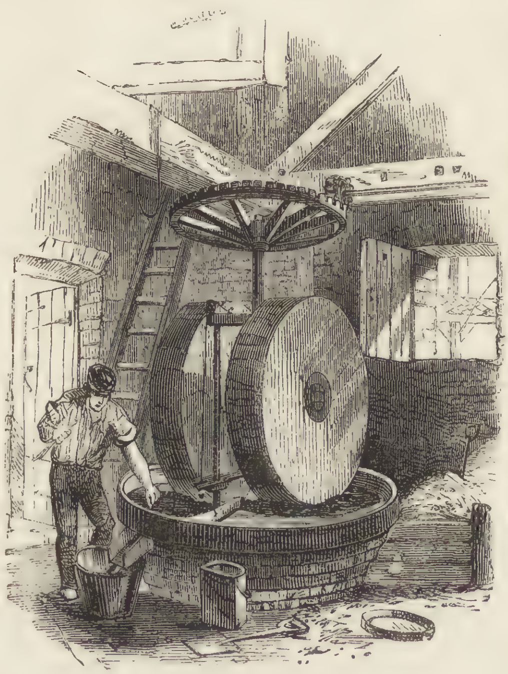


Fig. 566. GRINDING CHICORY.

$2\frac{1}{2}$ tons. This is surrounded by a sheet-iron border, and as the chicory is crushed out by the action of the runners, it is collected and thrown under them again by means of a scraper, adjusted to the proper curve and mounted on an axis parallel with the central axis: this scraper can also be adjusted to different heights. When the chicory is sufficiently crushed, a hopper is opened at the side, and the powder is discharged into a vessel placed to receive it. It is then bolted through sieves to different degrees of fineness, after which it is ready for sale. According to another method, the roasted chicory is crushed into nibs, which are again picked over and then sorted into sizes by bolting. These nibs, as well as the powder, are sold by the grocers.

The powdered chicory resembles coffee, but is finer in the grain and of a lighter brown colour. When put into water it melts almost entirely away. It soils the fingers more than coffee, and on this account may be distinguished therefrom. The presence of chicory may be detected in coffee by putting a spoonful of coffee gently into a tumbler of clear cold water: if pure it will float on the surface; if not, the chicory will separate and discolour the water as it subsides. In Germany the infusion of chicory is taken as a beverage by persons in humble life: in this state the flavour is that of a sharp sweetish wort, resembling the taste of liquorice, and in colour similar to that of dark sherry.

In its fresh state chicory, or succory *(Cichorium Intybus)*, is said to be a good tonic, and to have the effect of an aperient. The dandelion tribe is so widely diffused that it is probably intended by nature for the benefit of man and animals. The presence of chicory in coffee is said to give *body* to that beverage, to deepen its colour, and to assist that soft and pleasing aroma which makes coffee acceptable. This however is very doubtful. It may also diminish, in some degree, the constrictive effects of coffee. The proper proportion is 2oz. of chicory to 16oz. of coffee, and if a larger proportion be added and the price of coffee be charged, the addition of the cheaper article is a fraud. It is stated that half, or even two-thirds chicory is sometimes added. Of course the only safeguard for the consumer is to grind his own coffee and add the chicory himself. It is stated that in 1848, for 36,000,000lbs. of coffee, 12,000,000lbs. of chicory were sold; and some time ago it was proposed in parliament to impose a duty of 4*d.* per lb. on home dried chicory, with a view of lessening the use of it, or even of throwing it out of use altogether, as was effectually done some years ago, in the case of Hunt's celebrated roasted corn. It was stated, however, that the moderate use of chicory helps the sale of coffee. In April 1844, when a debate on the budget took place in the House of Commons, Mr. Baring observed that "we were mistaken about chicory, in thinking that the use of it prevented the consumption of coffee: he believed that chicory was mixed to a large extent with bad coffee. When Lord Spencer first proposed the reduction of the duty on chicory, the result was, that a certain amount of bad coffee, which would not pass in the market, was by admixture with chicory made to go down. People were wrong in supposing that chicory made bad coffee; he believed that the foreign coffee, which we so much preferred, contained one-third chicory. Cross the channel, and in point of fact all the coffee you drink contains one-third part of chicory."

A correspondent in *Chambers's Edinburgh Journal* (No. 304, N. S.) states that chicory must be regarded altogether as an adulterant: that the best coffee all over the continent is obtained by *roasting high.* "The rule is to roast as high as possible without burning; and the higher the roasting which the bean will stand, the better will be the coffee. When the beans are too ripe, the fine pale green colour has vanished and they are sooner burnt; and likewise, when unequal in size, one portion will burn before the other is highly enough roasted. To make the beverage good, a large quantity of ground coffee must be used, and the pot

must never by any means be allowed to boil. Abundance of sugar is likewise necessary."

Prussian chicory is considered as the best. British chicory when roasted is much paler in colour and of inferior value. A factitious colour is given to it by means of Venetian red (sesquioxide of iron). The great demand for chicory has led to its extensive adulteration; first, by what is called *Hambro' powder*, which consists of roasted and ground peas, damaged corn, &c., coloured with Venetian red; and secondly, by *coffee flights*, the thin membrane which separates from coffee seeds in the act of roasting. Parsnips, turnips, &c. are also sliced and roasted as substitutes for chicory. Chicory is used for adulterating snuff, and for colouring porter.

CHIMNEY, (French *Cheminée*, from Latin *Caminus*, a furnace,) a contrivance for carrying off the smoke of a fire or furnace. It also increases the draught of the fire, and promotes the ventilation of the house or room from which it opens. History has failed to record the inventor, or to define the place where the chimney was first used. Chimneys seem to have been common at Venice before the middle of the fourteenth century. An inscription over the gate of the school of Santa Maria della Carita states, that in 1347, a great many chimneys were thrown down by an earthquake, a fact which is confirmed by John Villani, who refers the event to the evening of the 25th of January. Chimneys had also been in use at Padua before 1368, for in that year Galeazo Gataro relates, that Francisco da Carraro, lord of Padua, came to Rome, and finding no chimneys in the inn where he lodged, because at that time fire was kindled in a hole in the middle of the floor, he caused two chimneys, like those that had been long used in Padua, to be constructed by the workpeople he had brought with him. Over these chimneys, the first ever seen in Rome, he affixed his arms, which were remaining in the time of Gataro. Winwall House, in Norfolk, which has been described as the most ancient and perfect specimen of Norman domestic architecture in the kingdom, has not only recessed hearths, but flues rising from them, carried up in the external and internal walls. Now, if Winwall House really be an Anglo-Norman edifice, its chimneys must have been built in the twelfth century, and, consequently, the claim of the Italians to the invention cannot be supported. The chimneys at Kenilworth and Conway were also probably erected anterior to the date of those on which the Italians rest their claim. Leland, also, in his account of Bolton Castle, which he says was "finiched or Kynge Richard the 2 dyed," notices the chimneys. "One thynge I muche notyd in the hawle of Bolton, how chimeneys were conveyed by tunnells made on the syds of the walls betwyxt the lights in the hawle, and by this

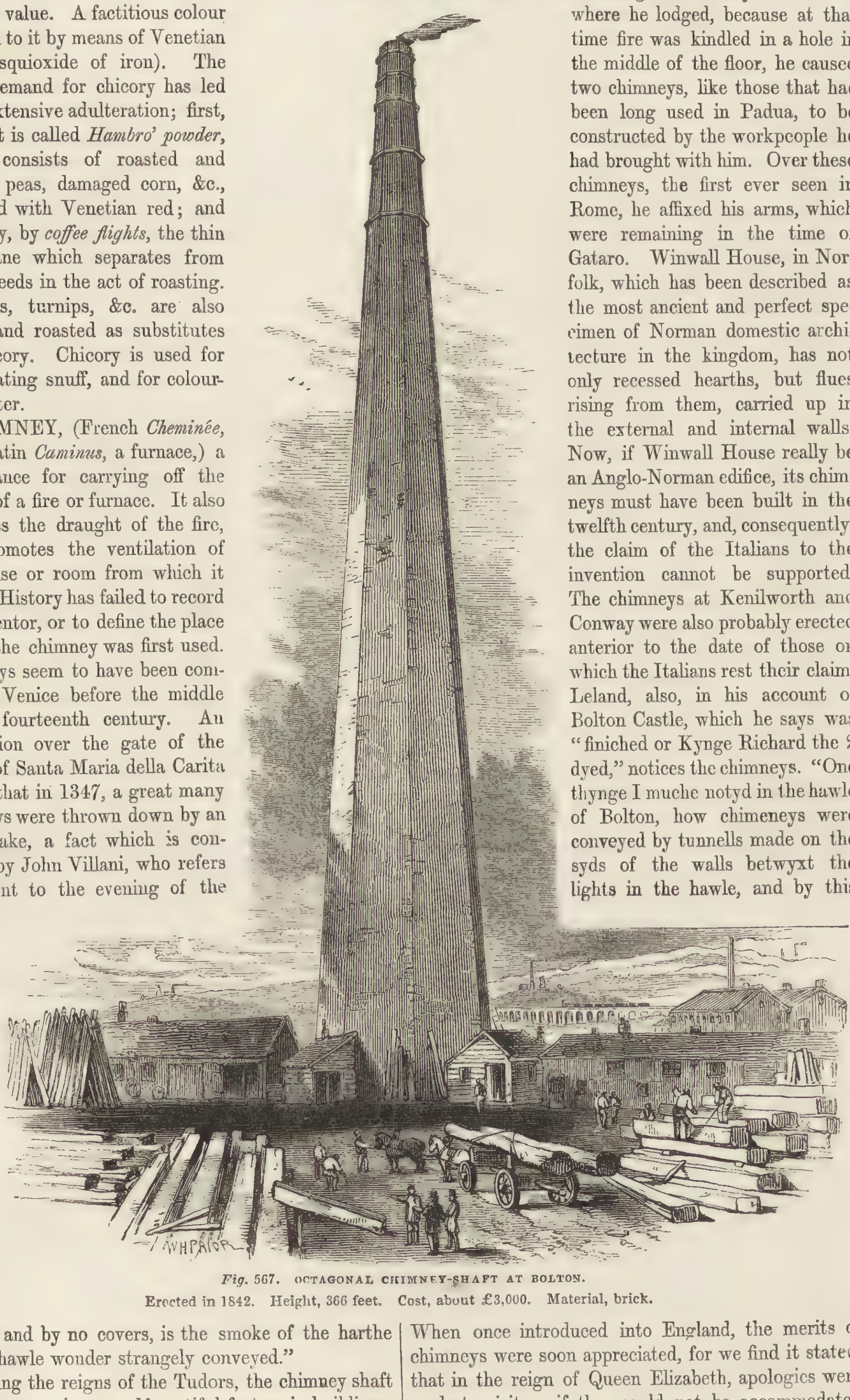


Fig. 567. OCTAGONAL CHIMNEY-SHAFT AT BOLTON.
Erected in 1842. Height, 366 feet. Cost, about £3,000. Material, brick.

means, and by no covers, is the smoke of the harthe in the hawle wonder strangely conveyed."

During the reigns of the Tudors, the chimney shaft became a prominent and beautiful feature in buildings. When once introduced into England, the merits of chimneys were soon appreciated, for we find it stated, that in the reign of Queen Elizabeth, apologies were made to visitors if they could not be accommodated

with rooms provided with chimneys, and ladies were frequently sent out to other houses, where they could have the enjoyment of this luxury, for such it must be called at this period, when the poorer class of houses was not yet furnished with it.

The first object proposed to be accomplished by chimneys was to discharge into the air the products of combustion, instead of allowing them to spread over the apartment. With the huge wood fires of our ancestors, the large hearth recess and the capacious flue did not interfere with the accomplishment of the object proposed; but when fire-places were introduced into small rooms, and coal was substituted for wood, the arrangements which were suited to the baronial hall or kitchen did not apply. Science was unable, or did not condescend, to investigate the subject, and thus the defects of chimneys continued to exist through many generations. One great defect arose from the great capacity of the flue in proportion to the extent of the fire, the heat of which was often insufficient to determine an upward current for carrying off the smoke. It is now a matter of every day experience, that the force of the draught in a chimney is so much the greater as the column of air which passes up it is longer or more heated; or, in other words, the taller the chimney, or the hotter the fire, the more rapid will be the draught. The ascentional force of this current is the difference between the weight of the column of heated air in the chimney, and a column of the surrounding atmosphere of equal height. The draught therefore is increased by increasing the perpendicular height of the chimney. Its length in a horizontal direction does not increase, but diminishes the draught, by cooling the air before it gets into the effective part of the flue. The draught is also increased, by making all the air which enters the chimney pass through or very near the fuel; for when much air gets into the chimney above the fire, by having a high mantel-piece, the mass of air in the chimney cannot get sufficiently heated.

It is a law of expansion for atmospheric air and all gases, that they dilate almost equally and very nearly in proportion to the increase of temperature. According to Gay Lussac, 1,000 cubic inches of air at the freezing temperature increase in bulk to 1,375 cubic inches at the temperature of boiling water. For an increase of temperature, therefore, from 32° to 212°, amounting to 180°, the increase of volume is 375 parts in 1,000, or $\frac{3}{8}$ of the whole bulk; and since the expansion is uniform, the increase of volume for 1° will be found by dividing this by 180, which will give an increase of $20\frac{5}{6}$ parts in 10,000 for 1° of Fahrenheit's thermometer. The recent experiments by Magnus and Regnault have thrown a doubt on the correctness of this result. By methods perfectly independent of each other, these philosophers have arrived at 0.3665, instead of 0.375, as the true co-efficient for the expansion of atmospheric air.

Now as this law of expansion applies equally to air in motion as to air in a state of rest, we can thus calculate the amount of dilatation undergone by the column of air in a chimney from the heat of the fire in the grate. But as the heat is constantly varying, so also is the volume of ascending air. The air of the room which passes through the fire and undergoes a chemical change is intensely heated, and passing up the flue becomes reduced in temperature at every step. The air which rushes into the cavity above the fire becomes also suddenly expanded, rises, and, mingling with the heated gaseous products of combustion, diminishes somewhat of their temperature while it augments their bulk. The mean temperature of the heated ascending column may be found by taking the temperature a short distance above the burning fuel, and also at the top of the chimney; by adding these two results together, and dividing by two, we get the mean temperature, or a near approximation thereto. We are then able to calculate the force of the draught by applying one of those rules which scientific men have formed for the purpose. The method of calculation proposed by Montgolfier is very simple, and appears, from recent inquiries, to be accurate. It is this:—Ascertain the difference in height between two equal columns of air when one is heated to a certain temperature, the other being the temperature of the external air, and the force of the draught, or the rate of efflux, is equal to the velocity that a heavy body would acquire by falling freely through this difference of height.

Now the space through which a heavy body falls in perpendicular height in one second is rather more than sixteen feet; but, by the law of accelerating forces, the velocity of a falling body at the end of any given time is such as would carry it, in an equal time, through twice the space through which it has fallen in that time; or the velocity in feet per second is equal to 8 times the square root of the number of feet in the fall; or, to the square root of the number obtained by multiplying 64 by the height of the fall in feet.

When the force of the draught of a chimney is the difference in weight between two columns of air caused by the expansion of one of these columns by heat, the decimal 00208 which represents the expansion of air by 1° of Fahrenheit must be multiplied by the number of degrees the temperature is raised, and this product again by the height of the heated column. Thus if the height of the column is 50 feet, and the increase of temperature 20°, we have $20 \times .00208 \times 50 = 2.08$ feet; or 52.08 feet of hot air will balance 50 feet of the cold air; and the velocity of efflux of the heated column when pressed by the greater weight of the colder column will be equal to $8\sqrt{2.08} = 11.54$ feet per second.

The mean temperature of the heated ascending current in a chimney is much greater than 20° above that of the colder column with which it is compared; but it is most probable that air expands more proportionally at high temperatures than at low ones for equal increments of heat. As the law of expansion for high temperatures has not, as far as we know, been determined, it was thought better to select an example within the range of our knowledge, than to assume a higher temperature, which would more nearly represent the conditions of the case.

By the same means, the efflux of air, under any given pressure, can also be calculated. The pressure being known, we calculate the height of a column of air equal in weight to this pressure. Thus if the pressure be equal to one inch of mercury, water is 827 times the weight of air, and mercury 13.5 times the weight of water; therefore $827 \times 13.5 = 11{,}164$ inches, or 930.4 feet; and according to the rule $8\sqrt{930.4} = 244$ feet per second for the velocity of efflux under the pressure of one inch of mercury.

In these cases, however, there must be an allowance for loss by friction, which will vary according to the nature and size of the chimney shaft, and also according to the velocity of the air. The retardation of the air by friction, in passing through straight tubes, will be directly as the length of the tube and the square of the velocity, and inversely as the diameter.

In this way the action of chimneys is brought within the domain of science. There are, however, practical difficulties and special cases which usually come under the treatment of the smoke-doctor; these may all be resolved by reference to well-known scientific principles, but, unfortunately, the smoke-doctor is not always—indeed, very seldom, a man of science. The following cases of smoky chimneys and the method of cure will include as much as need be said on this subject.

Chimneys may smoke for want of a sufficient supply of air. This is sometimes the case in a new house, where doors and windows fit tightly and accurately, so that scarcely a chink is left for the admission of air. Or, if the house be not new, the windows and doors are often listed, sandbags are placed over the junction of the two window-frames, and a thick mat closes the bottom of the door, and even the key-hole is often stopped. It is no wonder that, under such circumstances, the chimney should smoke; for the air necessary to support the fire must come down the chimney (the only way left for it) instead of passing through the fire and up it. To ascertain in a rough way how much air is required per minute to make the fire burn well without smoking, set the door open until the fire is burning properly, then gradually close it until smoke again begins to appear. Then open it a little wider, and hold it in such a position as will admit the necessary supply. Now observe the width of the open crevice between the edge of the door and the rabbet into which it would shut. Suppose this distance to be half an inch in a door eight feet high; the room would, in such a case, require for the entrance of the air an aperture equal to 48 square inches, or a hole six inches by eight inches. This, however, would be more than is usually required. Dr. Franklin found that a square opening of six inches to the side was a good medium size for most chimneys. But now comes the difficulty, (at least in English houses, where no air duct is provided by the architect and builder, as in the Polignac fire-place,) where to make this opening. If made in the door, it not only interferes with the privacy of the room, but admits of cold draught to the back and feet of those sitting near the fire; if made in the window, it brings a cataract of cold air down upon the heads of the inmates.

It has been proposed to cut a crevice in the upper part of the window-frame, and to place below this a thin shelf, sloping upwards, in order to direct the air towards the ceiling, where, mingling with the heated air of the apartment, it would mitigate its temperature, and bring it down again to feed the fire. The objection to this plan is, that it would cool the room; but as fresh air admitted from any other source would have a similar cooling effect, it is not easy to propose a better plan. An old-fashioned contrivance for kitchens was to place in one of the spaces of the window-frame a circular tin plate, containing a wheel mounted on an axis, the radii or vanes being bent obliquely: these being acted on by the entering air, forced it round like the vanes of a windmill, and at the same time dispersed the air to a certain extent, and prevented a distinct draught from being felt. Another method was to take out a pane of glass and substitute a tin frame, giving it two springing angular sides, and being furnished with hinges below, it could be drawn in more or less above, so that the incoming air might be directed upwards, and regulated as to quantity A contrivance has lately been introduced for ventilating rooms; but when there is a fire in the room, it must serve the purpose of introducing air instead of letting it out. It consists of a number of strips of plate glass, arranged after the fashion of a Venetian blind, occupying the position of one of the panes of glass in the upper window-frame. By a little adjusting motion, the strips can be separated more or less apart, to regulate the supply of air, or closed entirely, so as to exclude it. Perforated panes of glass have also been introduced as ventilators; but they must also bring air into the room instead of letting it out, when a fire is burning.

A second cause of smoky chimneys arises from the size of the fire-place; it may be too wide or too high. Dr. Franklin recommended that the openings in the lower rooms should be about 30 inches square and 18 deep; and those in the upper rooms only 18 inches square and not quite so deep; the intermediate openings diminishing in proportion to the height of the funnel.

But the funnel itself may be too high compared with the size of the fire. The hot air ascending to a certain height may distribute its heat to the air in the upper part of the flue, so that the whole may cool down, and the column within the flue be nearly of the same weight as an equal column on the outside. In such a case, there will be little or no draught to carry off the smoke, and it will, therefore, enter the room.

But it more frequently happens that the funnel is too short. The remedy in such case is to contract the opening of the chimney, so as to force all the air that enters to pass through or very near the fire.

In some houses, instead of having a separate chimney for each room or fire-place, the flue is bent or turned from an upper room into the flue of another fire from below. In such a case, the upper chimney is too short, since the length can only be estimated

from the place where it enters the flue of the lower room; and this, in its turn, is also shortened in efficient length by the distance between the entrance at the second funnel and the top of the stack; for all that part being supplied with air from the second funnel, adds no force to the draught; and if there is no fire in the second chimney, it cools the hot current of the first, and so diminishes the draught. The remedy in this case is to close the opening of that chimney in which there is no fire.

Chimneys often overpower each other, and so cause them to smoke. If, for example, there are two fire-places in one large room, with fires in each, and the doors and windows closed; if the two fires do not burn equally well, either from not being lighted at the same time, or not equally supplied with fuel, or from any other cause, the stronger fire will overpower the weaker, and draw the air down its funnel to supply its own demand. The air descending the funnel of the weaker fire brings the smoke with it, and thus fills the room. Two chimneys in different rooms which communicate by a door may also act in this way whenever the door is opened; so, also, in a house where all the doors and windows fit tightly, a strong kitchen chimney on the lowest floor may overpower any other chimney in the house, and draw air and smoke into the rooms as often as a door communicating with the staircase is opened. Dr. Franklin mentions the case of a nobleman's house in Westminster afflicted with this troublesome complaint. It was a new house, and after the owner had paid for it, and discharged all claims, he had to expend 300*l.* more before the smoky chimneys were cured. Of course, the only remedy for this disorder is, to provide each room with the means of furnishing the fire-place with a sufficient supply of air for the combustion of the fuel. When will architects and builders be convinced of the fact, that fire-places, as well as human beings, require constant supplies of fresh air, and that it is their duty to provide every room with air-channels, placed so as to feed the fire without annoying the inmates?

Another fruitful source of smoky chimneys is, when their tops are commanded by higher buildings, or by a hill, so that the wind blowing over them, falls like water over a dam, sometimes almost passing over the tops of the chimneys, and beating down the smoke. If the funnels cannot be raised, so that their tops may be of the same height, or higher than the eminence, the only remedy is to mount one of those ugly contrivances with which the chimney doctors delight to satirise the architect and builder, and which are thus enumerated by an amusing writer in Chambers's *Edinburgh Journal*:—"The simplest of all consists in the well-known revolving bonnets or cowls, with wind-arrows on their summits; which, by the way, were once called Bishops in Scotland, while a friend assures me, that in the west of England he has heard them styled Presbyterians. The philosophy of this contrivance is sufficiently simple, in whichever direction the wind blows, the mouth of the chimney is averted from it. This principle has its development in a thousand devices—some looking like Dutch ovens come up to see the world, some like half sections of sugar loaves, some like capital H's, and sundry other pleasing objects. The red chimney-pots, too, have contrivances of a similar intention, in the diverging spouts and cavities and twists which some of them delight in. A different species, is the perforated whirling variety, which seem pertually whizzing round for the mere fun of the thing, since any good they do is extremely apt to escape detection. They are a lively-looking apparatus; but on squally nights, and when the pivot becomes a little rusty, the musical sounds they give forth can scarcely be considered agreeable. Among the more ingenious of smoke-curers, an invention of recent origin, named the *Archimedean screw ventilator*, deserves a place. It consists, as its name implies, of wind-vanes attached to the extremity of a revolving screw. When the wind strikes these vanes, it produces a rapid revolution of the screw, which is thus supposed to *wind up* the smoke or vitiated air from below. Perhaps it serves the proposed end; but whether the positive advantage thus gained is not lost by the obstruction of such apparatus to the free passage of smoke in calm weather, is a point, in my estimation, more than questionable. For the relief of such chimneys as only smoke in windy weather, perhaps, this and other forms of external apparatus are best adapted. Another invention of equal merit, is a chimney-cap of metal externally grooved in a series of spiral curves up the pipe, which end in a kind of mouth-piece, from whence the smoke issues. The wind, when impelled against this apparatus, is supposed to take somewhat of the direction of the spiral grooves, and thus to form an upward current to assist the emission of the smoke." One of the most recent of this class of inventions is *Day's wind-guard*, which consists of an octagonal metallic chimney-cap, having four slits in it, which are protected by projecting pieces or slips of metal. When a current of air strikes in any direction against the cap, it reflects or turns the air in such a manner, as immediately to produce a draught up the pipe. "In casting one's eye down the long streets of the smoky city, in taking a survey of the roofs and their tormented chimneys, the infinity of other contrivances is so great, that it is scarcely a poetical hyperbole to say our pen starts back from it. Here is patent upon patent, scheme after scheme, each doing its best, no doubt, to obtain the mastery over that simple thing—smoke; and each with a degree of success of a very hopeless amount. There appears to me something intensely ludicrous in these struggles against what seems to be an absurd, but an invincible foe; the very element of whose success against us lies in our not strangling him in his birth. Many obstacles are in the way, no doubt; there are obstacles in the way of every good; but I have little doubt, that had the perverted ingenuity which has mis-spent itself upon the chimney-pots been directed to the fire-place, we might have now had a different tale to tell. The smoke nuisance is laughed at as a minor evil, by a great practical people like ourselves, who heroically make up their minds to put up with it;

but when it is considered as an item in the comfort, cleanliness, and health of a whole nation, it assumes, or should assume a different position."

We do not by any means affirm that the above contrivances are always effectual in the cure of smoky chimneys; for it is easy to imagine cases where chimneys will, or rather must smoke, in spite of the whole host of caps, cowls, and vanes. For example, when a commanding eminence is further from the wind than the chimney commanded, the wind would, as it were, be dammed up between the house and the eminence, and force its way down the chimneys in whatever position the turn-cap or other contrivance might be situated. Dr. Franklin mentions a city in which many houses were tormented with smoky chimneys by this operation, for their kitchens being built behind, and connected by a passage with the houses, the tops of the kitchen chimneys were thus lower than the tops of the houses, and thus, when the wind blew against the backs of the houses, the whole side of a street formed a dam, and the obstructed wind was forced down the kitchen chimneys, and passed along the passages into the houses, and so into the street. This was especially the case when the kitchen fires were burning badly. In summer the annoyance assumed a different form, for the smoke was wafted from the kitchen chimneys into the chambers of the upper rooms.

Chimneys, which otherwise draw well, will often smoke from the improper situation of a door. Thus when the door and the chimney are on the same side of the room, and the door, being in the corner, is made to open against the wall, as is usually done, to have it more out of the way, it follows that, when the door is partly opened, a current of air rushes in and passes along the wall into and across the opening of the fire-place, and whisks the smoke into the room. This happens more frequently when the door is being shut, for then the force of the current is increased, and persons sitting near the fire feel all the inconvenience both of the draught and the smoke. A remedy may be found by an intervening screen, projecting from the wall and passing round a great part of the fire-place; or still better, by shifting the hinges of the door, so as to throw the air along the other wall.

A room with no fire in it is sometimes filled with smoke from the funnel of another room, in which a fire is burning. This arises from changes in density of the air in the cold funnel, from changes in temperature by day and by night, as well as from changes in the direction of the wind. It is found that when the temperature of the outer air and of that in the funnels is nearly equal, the air begins to ascend the funnels as the cool of the evening comes on, and this current will continue till nine or ten o'clock next morning; then, as the heat of day approaches, it sets downwards and continues to do so till evening; it then changes again and continues to go upwards during the night. Now when the smoke from the tops of neighbouring funnels passes over the tops of funnels which are drawing downwards, the smoke is also drawn down and descends with the air into the chamber. The remedy proposed by Dr. Franklin, was to contract the opening of the chimney to about two feet between the jambs, and to bring the breast down to about three feet of the hearth. An iron frame is then placed just under the breast, and extended to the back of the chimney, so that a plate of iron may slide horizontally backwards and forwards in the grooves on each side of the frame; this plate, when thrust quite in, fills up the whole space, and shuts up the chimney entirely when there is no fire. But when there is a fire, it can be drawn out, so as to leave between its further edge and the back, a space of about two inches, which is sufficient for the smoke to pass; and so large a part of the funnel being stopped by the rest of the plate, the passage of warm air out of the room up the chimney is in great measure prevented, as is also the cold air from crevices to supply its place. The effect is seen in three ways:—1. When the fire burns briskly in cold weather, the howling or whisking of the wind, as it enters the room through the crevices when the chimney is open, ceases as soon as the plate is slid in to its proper distance. 2. Opening the door of the room about half an inch, and holding the hand against the opening near the top of the door, you feel the cold air coming in against your hand, but weakly if the plate be in. Let another person draw it out, so as to let the air of the room go up the chimney with its usual freedom in open chimneys, and you immediately feel the cold air rushing in strongly. 3. If something be set against the door, just sufficient when the plate is in to keep the door nearly shut, by resisting the pressure of the air that would force it open, then, when the plate is drawn out, the door will be forced open by the increased pressure of the outward cold air endeavouring to get in, to supply the place of the warm air that now passes out of the room to go up the chimney. "In our common open chimneys," says the Doctor, "half of the fuel is wasted, and its effect lost; the air it has warmed being immediately drawn off."

The form of the chimney-pot has also an influence on the free passage of the smoke. Many of those fancy chimney-pots ornamented, singly or clustered together, will cause the chimneys to smoke in strong winds; the ornaments serving as points of resistance to the wind, after reflecting it down the chimney; and the clustered arrangement presenting a broad resisting surface, so that the wind, in blowing against them, rises up along the surface, and blows strongly over the mouths of the pots, so that the smoke cannot force its way through the blast. In Venice, the top of the flue is rounded into the true form of a funnel, and this is often found to answer the purpose; but, at present, we do not know of any remedy except a turn-cap, or one of the many elegant contrivances which give such wonderful variety to the sky line of most of our houses and public buildings.

Cases of smoky chimneys may arise, which may puzzle the science of the most accomplished smoke doctor. We borrow two such cases from Franklin. "I once lodged," he says, "in a house in London, which, in a little room, had a single chimney and

funnel. The opening was very small, yet it did not keep in the smoke, and all attempts to have a fire in this room were fruitless. I could not imagine the reason; till at length, observing that the chamber over it, which had no fire-place in it, was always filled with smoke when a fire was kindled below, and that the smoke came through the cracks and crevices of the wainscot, I had the wainscot taken down, and discovered that the funnel which went up behind it, had a crack many feet in length, and wide enough to admit my arm; a breach very dangerous with regard to fire, and occasioned, probably, by an apparent irregular settling of one side of the house. The air entering this breach freely, destroyed the drawing force of the funnel. The remedy would have been, filling up the breach, or rather rebuilding the funnel; but the landlord rather chose to stop up the chimney."

The second case occurred at the house of a friend near London. "His best room had a chimney, in which he told me he never could have a fire, for all the smoke came out into the room. I flattered myself I could easily find the cause, and prescribe the cure. I opened the door, and perceived it was not want of air. I made a temporary contraction of the opening of the chimney, and found that it was not its being too large that caused the smoke to issue. I went and looked up at the top of the chimney, its funnel was joined in the same stack with others, some of them shorter, that drew very well, and I saw nothing to prevent its doing the same. In fine, after every other examination I could think of, I was obliged to own the insufficiency of my skill. But my friend, who made no pretension to such kind of knowledge, afterwards discovered the cause himself. He got to the top of the funnel by a ladder, and looking down, found it filled with twigs and straw cemented by earth, and lined with feathers. It seems, the house, after being built, had stood empty some years before he occupied it; and he concluded that some large birds had taken the advantage of its retired situation to make their nests there. The rubbish, considerable in quantity, being removed, and the funnel cleared, the chimney drew well, and gave satisfaction."

It has been remarked, that chimneys situated in the north wall of a house, do not draw so well as those in a south wall; because when cooled by north winds, they are apt to draw downwards. Hence, chimneys enclosed in the body of a house are more favourably situated than those in exposed walls. Chimneys in stacks often draw better than separate funnels, because those that have constant fires in them warm those in which there are none.

Ascending and descending currents in chimneys are thus explained by Dr. Franklin:—"In the summer time, when no fire is made in the chimneys, there is, nevertheless, a regular draft of air through them, continually passing upwards from about five or six o'clock in the afternoon, till eight or nine o'clock next morning, when the current begins to slacken and hesitate a little for about half an hour, and then sets as strongly down again, which it continues to do till towards five in the afternoon, then slackens and hesitates as before, going sometimes a little up, then a little down, till, in about half an hour, it gets into a steady upward current for the night, which continues till eight or nine the next day; the hours varying a little as the days lengthen and shorten, and sometimes varying from sudden changes in the weather; as, if, after being long warm, it should begin to grow cold about noon, while the air was coming down the chimney, the current will then change earlier than the usual hour, &c. This property in chimneys, I imagine, we might turn to some account, and render improper for the future the old saying, 'As useless as a chimney in summer.'" The doctor then shows how the chimney might be converted into a cool larder for summer, and then goes on to explain the cause of the phænomena he has described. "In summer time there is generally a great difference in the warmth of the air at mid-day and midnight, and, of course, a difference of specific gravity in the air, as, the more it is warmed, the more it is rarefied. The funnel of a chimney, being for the most part surrounded by the house, is protected, in a great measure, from the direct action of the sun's rays, and also from the coldness of the night air. It thence preserves a middle temperature between the heat of the day and the coldness of the night. This middle temperature it communicates to the air contained in it. If the state of the outward air be cooler than that in the funnel of the chimney, it will, by being heavier, force it to rise, and go out at the top. What supplies its place from below, being warmed in its turn by the warmer funnel, is likewise forced up by the colder and weightier air below; and so the current is continued till the next day, when the sun gradually changes the state of the outward air, makes it first as warm as the funnel of the chimney can make it, (when the current begins to hesitate,) and afterwards, warmer. Then, the funnel, being cooler than the air that comes into it, cools that air, makes it heavier than the outward air,—of course, it descends; and what succeeds it from above, being cooled in its turn, the descending current continues till towards the evening, when it again hesitates, and changes its course, from the change of warmth in the outward air, and the nearly remaining same middle temperature in the funnel. . . . If that part of the funnel of a chimney which appears above the roof of a house be pretty long, and have three of its sides exposed to the heat of the sun successively—viz. when he is in the east, in the south, and in the west, while the north side is sheltered by the building from the cool northerly winds, such a chimney will be often so heated by the sun, as to continue the draft strongly upwards through the whole twenty-four hours, and often for many days together. If the outside of such a chimney be painted black, the effect will be still greater, and the current stronger."

Wide chimneys are not so liable to have their draught affected by strong winds as narrow ones. It is therefore desirable to build them tolerably wide, and to reduce the width, if necessary, by means of a sliding register-plate. When a number of furnace

flues are conducted into one vertical chimney-stalk, the draught of the several fires is improved, and the products of combustion are conveniently got rid of.

A great improvement has taken place of late years in the building of these costly structures. The usual expensive scaffolding is entirely superseded, by leaving recesses within the chimney at regular intervals, a few feet apart, for receiving the ends of stout wooden bars placed across the chimney, so as to form a sort of internal temporary ladder. By this means, and with the assistance of ropes and pulleys, all the building materials are hoisted as they are wanted. In this way, 1 bricklayer with the assistance of a labourer, can, in a few weeks, raise a chimney 40 feet high, 5 feet 8 inches square outside, 2 feet 8 inches inside at the base, 28 inches outside, and 20 inches inside at the top. The erection is facilitated, and the solidity increased, by building it in two or more successive plinths or recedures. Such chimneys must be thick and substantial near the base, in order to sustain the great heat of the fire, and prevent the hot current from cooling too rapidly. Dr. Ure says:—"When many flues are conducted into one chimney stalk, the area of the latter should be nearly equal to the sum of the areas of the former, or at least of as many of them as shall be going simultaneously. When the products of combustion from any furnace must be conducted downwards, in order to enter near the bottom of the main stalk, they will not flow off until the lowest part of the channel be heated, by burning some wood shavings or straw in it, whereby the air syphon is set going. Immediately after kindling this transient fire at that spot, the orifice must be shut by which it was introduced; otherwise the draught of the furnace would be seriously impeded. But this precaution is seldom necessary in great factories, where a certain degree of heat is always maintained in the flues, or at least, should be preserved by shutting the damper plate of each separate flue, whenever its own furnace ceases to act. Some chimneys are furnished at top with a coping of stone-slabs, to secure their brickwork against the infiltration of rains, and they should be furnished with metallic conducting-rods, to protect them from explosions of lightning."[1]

At Mr. Thomas Cubitt's fine establishment at Thames-Bank, the chimney-shaft for the steam-engine is constructed in a peculiar manner. The chimney, which is circular, five feet in clear diameter all the way up, and 105 feet high, is built of very thin brick-work; that is to say, it is 14 inches thick at the bottom and 6 inches at the top; the bricks having been moulded for the purpose. It stands in the centre of a tower 17 feet square on the outside, formed of 14-inch walls all the way up, with hoop-iron bond in the centre of the walls at certain intervals. The first tier of this bond is 15 feet from the ground; the other tiers are put closer together, as they approach the top. Around the shaft, but not touching it, are stone steps leading to the top, with landings at certain intervals. Mr. Cubitt's chief reason for adopting this mode of construction was to obtain a more picturesque landmark for his establishment than a chimney-shaft; but he is of opinion that its ultimate cost will be less than that of a shaft. It economises the fuel to a considerable extent by keeping off cold air; and moreover, a shaft would have required more expensive arrangements for erection than the shaft and tower. The surrounding tower does not touch the shaft at any point; and, on standing on the top landing, and pressing the hand with moderate force against the stalk, the whole of the shaft can be rocked backwards and forwards through a range of a few inches. This rocking doubtless takes place in all tall shafts by the action of the wind upon them. As the tower does not touch the chimney, the most perfect facilities are thus afforded for ascertaining the effect of heat upon this height of brickwork; and an index having been set up on the topmost landing, under cover, which is 80 feet from the ground, it is found that this length of shaft becomes five-eighths of an inch longer when the fire is lighted than it is when cold.[2] Two thermometers are inserted into the brickwork, the bulbs of which curve into the chimney, so that the temperature of the ascending current can be ascertained by inspection at two points, one 25 feet from the bottom, and the other 30 feet from the top. The following are a few of the data which have been collected by observing these instruments. They were furnished by Mr. Porter to the Editor during a recent visit to Mr. Cubitt's establishment.

The fire is lighted about 5 A.M.

	Lower Thermometer.	Upper Thermometer.	Temperature of air in the Tower	
5.30	210°	190°	78°	82°
7.30	261	208	76	82
8 (Breakfast)	212	188	78	82
8.30	240	200		
10.30	254	214		
12 } (Dinner)	218	200		
12.30 } (Dinner)	180	110		
2	250	212	78	84
2.30	260	223	7¼-inch damper open. Water pressure $\frac{6}{10}$ths of an inch. Damper open 6 inches. Temperature in open air 56°.	
3	260	216		
3.30	262	223		

CHINA-WARE.—See PORCELAIN.

CHINTZ, a printed calico, in which figures of at least 5 different colours are printed on a white or light-coloured ground.

CHLORINE, a gaseous substance, (Cl. 36) discovered by Scheele, in 1774, but its elementary nature was first established by Davy in 1810, who proposed to abolish the unwieldly and inaccurate terms *dephlogisticated muriatic acid* and *oxymuriatic acid*, which

(1) Dictionary of Arts, Manufactures, &c. Our chief authorities in this article are Hood's Practical Treatise on Warming Buildings by Hot Water, &c. Second Edition, 1844; Dr. Franklin's celebrated Letter on Chimneys, addressed to Dr. Ingenhous, 1785; and Tomlinson's Treatise on Warming and Ventilation, published in Weale's Rudimentary Series, 1850.

(2) The reader is aware that the application of heat to clay causes it to contract, by driving off the moisture. When the clay has been burned into bricks, it then expands by heat Thus coke-ovens expand considerably by heat. The stone-coping of Waterloo Bridge expands and contracts so much by change of temperature as frequently to require pointing.

had been applied to it, and to substitute a name derived from its most striking physical quality, namely, its greenish yellow colour. The name chlorine (from χλωρὸς green), is now universally adopted.

Sea-salt (chloride of sodium) is the great natural source of chlorine. When required in large quantities for the purpose of the manufacturer, it is made by pouring diluted sulphuric acid on a mixture of common salt and oxide of manganese, contained in a large leaden vessel. [See BLEACHING.] The decomposition which ensues, will be understood from the following statement:—

Chloride of Sodium	Chlorine	Chlorine.
	Sodium	Sulphate of Soda.
Sulphuric Acid		
Peroxide of Manganese	Oxygen	
	Protoxide of Manganese	Sulphate of Manganese.
Sulphuric Acid		

Chlorine may also be readily procured by pouring strong muriatic acid upon finely powdered black oxide of manganese, contained in a retort or flask, and applying a gentle heat. The chemical changes which take place are as follows:—Muriatic, or as it is otherwise called, hydrochloric acid is a compound of chlorine and hydrogen: when this is mixed with a metallic protoxide, water and a chloride of the metal are produced; but when a peroxide, which contains twice as much oxygen as the protoxide, is used, a second portion of hydrochloric acid is decomposed by the oxygen in excess, which also unites with the hydrogen to form water, and the chlorine is set free.

Chlorine is very soluble in cold, but much less so in warm water. Hence it may be collected in bottles filled with water, at the temperature of not less than 90°, and inverted at the pneumatic trough: the stopples should be greased and inserted before the bottles are removed from the trough. Chlorine cannot be collected over mercury, as it combines at once with that metal. In the preparation of this gas, care must be taken not to allow it to escape in any quantity, as it is very suffocating, producing cough and irritation when inhaled only to a small extent. Its action, however, varies greatly with different individuals, and it is less irritating after the lungs have become accustomed to it by repeated use. When largely diluted with air, it is most pleasant and refreshing to many persons. Nevertheless extreme caution must be used in inhaling this gas in its most dilute form, and it should never be done as a remedial agent, except under medical advice.

Water at 60° absorbs about twice its volume of this gas, and acquires its colour and odour. By exposure to light, this solution is slowly changed by decomposition of water into hydrochloric acid, oxygen being at the same time liberated. Moist chlorine exposed to a temperature of 32°, forms yellow crystals of hydrate of chlorine.

The sp. gr. of chlorine is 2.47, and 100 cubic inches weigh 76.6 grains. It condenses to a yellow limpid liquid, under a pressure of about four atmospheres.

Chlorine is a supporter of combustion, and has a very strong chemical attraction for hydrogen and the metals. A lighted taper plunged into this gas, burns with a dull red light: the hydrogen of the wax is alone consumed, the carbon being separated in the form of a dense black smoke. If a piece of paper wetted with oil of turpentine be immersed in a bottle of chlorine, it will burn, the hydrogen of the turpentine uniting with the chlorine, while the carbon is separated as an abundant soot. Phosphorus takes fire spontaneously in chlorine. Copper-leaf and powdered antimony also burn in the gas. A mixture of equal volumes of chlorine and hydrogen explodes on the application of flame or the electric spark, hydrochloric acid being the result. Such a mixture exposed to the direct rays of the sun, immediately explodes: the two gases combine slowly under the action of diffused daylight: but they undergo no change in the dark.

A most valuable and characteristic property of chlorine is its bleaching power; the most fixed organic colouring principles are instantly decomposed and destroyed by it: indigo, which resists the action of strong sulphuric acid, has its blue colour effectually destroyed by chlorine. Dry chlorine however does not bleach: hence the presence of water is always necessary to bring about these remarkable changes. [See BLEACHING.—PAPER.]

Chlorine is also the best and most powerful disinfectant. Unlike other substances used for fumigation, such as brown-paper, vinegar, scents, &c., which merely disguise the ill odours, or the mephitic atmosphere, chlorine absolutely destroys them. It is probable, that most ill odours, &c. are compounds of hydrogen; hence, the chlorine enters into combination with the hydrogen, forming muriatic acid, and the other substance, whatever it may be, to which the hydrogen communicated virulence, falls harmless. The use of chlorine as a disinfectant requires care. It should be used in the form of bleaching powder mixed with water, and exposed to the air in shallow vessels, if possible on a high shelf. The powder (chloride of lime) is gradually decomposed by the carbonic acid of the atmosphere, and the chlorine being evolved, falls slowly down, and is diffused through the room. If the action is required to be quicker, a little dilute muriatic acid may be allowed to drop into the vessel, by suspending a funnel with a piece of tow in the stem, over the vessel containing the bleaching powder. Another method is to suspend in the apartment, cloths steeped in a solution of the bleaching powder; or, in the absence of bleaching powder, the gas may be generated by one of the methods before described, care being taken to avoid excess. It must however be particularly borne in mind, that chlorine in any form must only be used as an aid to proper ventilation. It is a necessary condition of health, that our houses and rooms be properly ventilated: there is no substitute for ventilation, any more than for washing or for general cleanliness. Chlorine, like medicine, ought in general to be used on special occasions and under advice. In a sick-room, where proper ventilation is often difficult, chlorine liberated in very minute quantities will often be found singularly refreshing; but in this, as in all other cases of fumigation with chlorine, all metals, such as fender, fire-irons, &c., ought to be

removed, for these become speedily tarnished by the action of chlorine.

When employed for disinfecting the wards of hospitals, &c., a pound of chloride of lime should be mixed with water in a hand-basin, and a pound measure of hydrochloric acid be poured upon it. The gas is evolved without heat. The persons concerned in the preparation of the materials, should tie a wet sponge over the nostrils, before going into the rooms.

There are several compounds of chlorine and oxygen, but the interest which attaches to them is chiefly scientific. Other compounds will be noticed under the names of the bases, [See POTASH—SODA—SEA-SALT, &c.;] and the compound of chlorine and hydrogen will be noticed under HYDROCHLORIC ACID.

CHLOROFORM. The name of this substance has reference to the constitution of formic acid, which is represented by C_2HO_3: it is an oxide of a hydrocarbon (C_2H) to which the term *formyle* has been applied. Chloroform would be represented by C_2HCl_3, that is to say, it has the same composition as formic acid, in which 3 equivalents of chlorine have taken the place of 3 equivalents of oxygen. Chloroform may be obtained by distilling alcohol, wood-spirit or acetone with a solution of chloride of lime. 1 pint of hydrate of lime is suspended in 24 parts of cold water, and chlorine passed through the mixture until nearly all the lime is dissolved. A little more hydrate is then added to restore the alkaline reaction, the clear liquid mixed with 1 part alcohol or wood-spirit, and after 24 hours, cautiously distilled in a very large vessel. A watery liquid containing a little spirit, and a heavy oil, collect in the receiver; the latter, which is the chloroform, is agitated with water, digested with chloride of calcium, and rectified in a water-bath. It is a thin colourless liquid, of agreeable etherial odour, and sweetish taste. Its sp. gr. at 65° is 1.48; it is kindled with difficulty, and burns with a greenish flame. Its boiling point is about 140°; the density of its vapour is 4.2. When this vapour is inhaled, it induces insensibility more rapidly and effectually than ether vapour: hence its use in the performance of painful surgical operations. When a few drops of chloroform are placed on the hand, evaporation speedily goes on, and produces a great degree of cold. Professor Brande says, "When poured upon water, the greater part sinks in globules, which are of a milk-white appearance when the chloroform is not perfectly free from alcohol. It is so little soluble in water, that 3 drops added to 9 ounces of distilled water and well shaken, did not wholly disappear, although they imparted a strong odour to the liquid."

Chloroform is prepared on a large scale by cautiously distilling good commercial chloride of lime, water and alcohol. The whole product distils over with the first portions of water.

CHOCOLATE. This agreeable and nutritious substance was introduced into Europe from Mexico by the Spaniards, in 1520, and its source and mode of manufacture was by them long kept secret. Linnæus was so fond of chocolate that he gave the specific name of *Theobroma* (θεὸς and βρῶμα, the food of gods) to the cacao-tree which produced it. The Mexicans call the tree *chocolalt;* hence our word *chocolate* applied to the prepared seeds.

The *Theobroma Cacao*, or chocolate-nut-tree, Fig. 568, is a small tree, of which whole forests occur in Demerara. The Mexican cacao, however, is yielded by another member of this family. The capsules of

Fig. 568. THE CHOCOLATE-NUT-TREE.

the fruit of this tree are large, somewhat resembling a cucumber, and containing from twenty to thirty seeds, arranged in five regular rows, enveloped in a pulp, which has a sweet and not unpleasant taste, and is frequently used as food in places where the tree is grown. The trees are evergreen, and bear fruit and flowers all the year through; but the usual times for gathering the fruit are June and December. The fruit which is produced in the West India Islands, Berbice, and Demerara, is much smaller than that of South America. By far the largest quantity of seeds received in this country is from the West Indies, and of these the Trinidad nuts are considered the best.

The species of this tree are somewhat numerous, and the fruits thereof vary in size, form, and the number of the seeds which they contain. "The general number is from twenty-five to thirty in each fruit; being more abundant as well as of better quality in the cultivated than in the wild plants. They vary much in bitterness, and in the quantity of oil they yield, not only according to the species from which they are obtained, but the manner in which they are treated after being gathered and taken out of the pulpy fruit. In some instances they are buried in the earth in heaps, and allowed to ferment for thirty or forty days; a process which greatly improves them, and destroys the germinating power of the seed. The different kinds met with in commerce derive their

names either from the place where they grow, or from some corruption of the native designation. The average size of good beans is that of a sweet almond, but somewhat thicker. The most esteemed of the known sorts is that termed *Soconuzco* or Mexican, with very small beans, with a remarkably fine flavour, and scarcely any acrid taste. These beans are always buried. This sort never comes to Europe. The next most valuable comes from the Esmeraldas, and has a very agreeable flavour: the chocolate prepared from it has a golden colour: it is seldom met with out of Mexico. The Guatemala cocoa consists of very large beans, very convex, often angular, and very much pointed at the one end. They contain much oil, and are mild, with a pleasant flavour. The beans from Guayaquil, which are three times as large as those of Soconuzco, are less prized than those of Guatemala. The Caracas or New Granada cocoa, which is among the more highly prized kinds that reach Europe, is obtained from the *Theobroma bicolor*, called by the natives Bacao, and cultivated at Carthago. The beans are of medium size, and very oily. But chocolate made of these alone is not very agreeable, and another kind is commonly mixed with them, which are much smaller and harder. Berbice cocoa beans are not unfrequently mingled with those of Granada. These are also smaller and thinner, but in other respects difficult to distinguish: the shell separates very easily from the kernel, which is reddish brown, and has a strong smell but a pleasant flavour. The Surinam and Essequibo cocoas are not unlike that from New Granada, but are harder, thicker, and not so sweet. All the foregoing are *earth-dried*, the following are called *sun-dried*, being merely collected in heaps and then turned over in the sun: they are consequently much cheaper. Brazilian, called also of Para, and of Maranham, is very extensively employed: the beans are small, smooth, long, somewhat flattened, externally reddish brown, with a bitter astringent taste: it is only worth half the amount of the former. The West Indian, called *Cocoa des Isles*, or *des Antilles*, is still less valuable, and is employed to form the low-priced cocoas and chocolates."[1]

According to Lampadius, the kernel of the West India cacao consists of:—

Fat oil	53.10
Azotized substances (theobromine)	16.70
Starch	10.91
Gum and colouring matter[2]	9.76
Lignine	0.90
Water and loss	8.63
	100.00

The substance named *theobromine* is white, pulverulent, and of a bitter taste, resembling *caffeine*. [See COFFEE.] It is sparingly soluble in hot water, and but little soluble in alcohol or ether.

The fruit of the cacao, like almonds, is covered with a thin skin or husk, which forms about 12 per cent. of the weight of the beans: it contains no fat, but, in addition to lignine or woody fibre, which forms half its weight, it yields a light brown mucilaginous extract by boiling in water. This husk or shell is known to the manufacturers of chocolate under the name of *cocoa, miserable*, or *destitute*. The demand for this article in Ireland is so great that in one year (1840) 612,122lbs. of *shells* were consumed, and only 4,000lbs. of the nut.

The following is Dr. Ure's analysis of Guayaquil cocoa:—

Concrete fat or butter of cocao dissolved out by ether	37
Brown extractive, got out by hot water after the operation of ether	10
Ligneous matter, with some albumine	30
Shells	14
Water	6
Loss	3
	100

The *butter of cacao*, or fatty matter of the nut, is of the consistence of tallow, of a white colour, and of a mild agreeable taste. It is not apt to become rancid by keeping. It is said to be very nutritious, and to act as an anodyne. It is particularly recommended for making ointments. Its proportion, as well as that of the other ingredients, varies greatly in the different sorts, as will be seen by comparing the above analyses. The West India kinds contain more of the butter than those from New Granada. It is therefore more advantageous to employ the latter in the manufacture of chocolate, and the former for extracting the solid oil for the manufacture of candles, soap, or pomades. The oil can be obtained by exposing the beans to strong pressure in canvass bags, after steaming, or soaking them some time in boiling water. 1lb. of cacao gives from 5 to 6 ounces of the butter: it has a reddish tinge at first, but becomes perfectly white by long boiling in water. This oil contains a large proportion of stearine, and is therefore solid at ordinary temperatures: it melts at 122°. It is soluble in boiling alcohol, but precipitates in cold. It is perfectly soluble in ether, which thus furnishes an easy method of detecting adulteration with beef-fat, suet, marrow, almond oil, wax, &c. It is less employed in this country than in France. A soap made with it and soda is an agreeable toilet article for those who are troubled with a rough harsh skin or chapped hands.[2]

The manufactured article, chocolate, is made to assume a variety of forms, to which various names are attached, according to the object proposed by the mode of manufacture. We will confine our attention chiefly to three forms, namely, chocolate *nibs*, *soluble* chocolate, and *chocolate*, properly so called, and lastly, *flake cocoa*.

The beans are received in bags, weighing from 1½ to 2 cwt. each, and the first process is to pick them,

(1) Penny Cyclopædia. Article *Theobroma*.

(2) The colouring matter, amounting to 2.01, was a reddish dye-stuff, somewhat akin to the pigment of cochineal.

(2) The soap and candles prepared from *cocoa-nut oil* have nothing to do with the article now under consideration. Cocoa-nut oil is obtained from the *cocos nucifera*.

for the purpose of separating any spoiled or mouldy portions. They are then gently roasted over a fire in an iron cylinder, provided with openings at the ends to allow the vapours to escape. The heat is first applied very slowly, in order to dissipate the moisture: a quick fire is injurious, as it hardens the surface. When the aroma begins to be well developed, the beans are turned out into shallow wooden coolers, and moved about every now and then with wooden rakes with long handles. There is a loss of 8lbs. or 9lbs. per cwt. in roasting. When quite cold, the beans are broken down in a hand-mill to the size of common split beans, and the shells (or *destitute*) are separated by a winnowing or corn-dressing machine.

The cocoa-nibs thus prepared are sold as an article of food; but they require two hours' boiling, as the inner seed-coat passes down into the substance of the cotyledons, rendering the prolonged application of heat and moisture necessary to dissolve the contents.

For making chocolate the roasted and crushed nut, entirely divested of its shell, is submitted to the grinding action of two horizontal mill-stones surrounded by a steam jacket, which raises them to a temperature of upwards of 200°. The top stone is the runner. The nibs are put into a hopper, from which they gradually descend down a shoot, the end of which touches in succession four leaves raised on the vertical axis which gives motion to the runner: by this means a shaking motion is given to the shoot, and the nibs are thus made to fall down in a gradual manner. The heat, the pressure, and the friction of the stones, reduces the nibs to a paste, and liberating the oil or butter of cacao renders it fluid. Escaping at the junction of the two stones, this fluid paste issues at an opening made for it at the side, (see Fig. 569,) where it is received by a shoot, and is conveyed to a second pair of mill-stones situated at a lower level, and similarly heated by means of a jacket of steam. The stones are here set closer together than

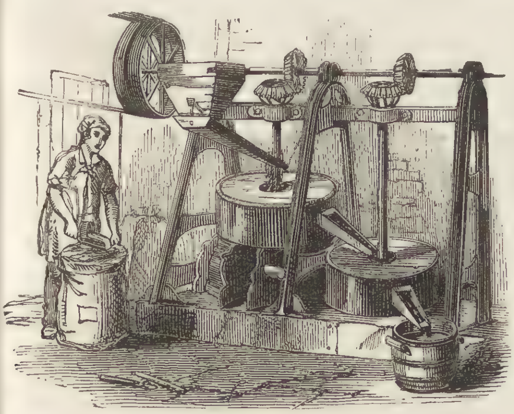


Fig. 569. CHOCOLATE MILL.

in the first pair, and by their action, all hard and gritty particles of the nut which escaped in the first grinding are broken down, and the paste flows down the shoot of the second pair of stones as a smooth shining equable fluid: it is received into a pan, where in cooling it solidifies into a hard cake.

In this state the bean will not form an emulsion with water, on account of the large proportion of concrete fat contained in it: to fit it for this purpose some additional substance must be introduced, to assist this emulsive union of the fat with water. Sugar, honey, treacle, gum, starch, flour, rice, and arrow-root, are well adapted for this purpose. On the Continent, vanilla, cinnamon, cloves, long-pepper, musk, or other perfume, are frequently added, but this is for making a fancy rather than a useful article.

For the purpose of mixing the different ingredients with the ground bean, the honey, treacle, arrow-root, &c., being reduced to the fluid state in large mixing pans of tinned copper heated by being surrounded by steam jackets, the ground bean is added in the proper proportion, and the whole well incorporated at the temperature which experience has determined to be the best. While still thin with the heat and agitation, the chocolate is poured into tin moulds arranged in a wooden tray, and quickly removed to a cool place where they are exposed to a draught of air. The moulds must be well shaken to insure the filling up of all the cavities, to give a sharp and polished impression, and to indent clearly those lines which divide the cake of chocolate into 8 equal parts, each part weighing a quarter of an ounce, the proper quantity for making a cup of chocolate, although the directions say two of the divisions or half an ounce. Care and experience are required in regulating temperature, for if the chocolate be introduced into the moulds too hot it will have a damp dull surface; and if not hot enough, it will not take the proper form. The tin moulds after the cakes are removed from them, are in a highly electric state, and will attract and repel light bodies. Of course the cakes are in an opposite electrical state. The difference between soluble chocolate and chocolate that requires boiling, (*Sir Hans Sloane's chocolate*, for example,) is that, in the former case, the materials, honey, sugar, &c., added to the nut and minutely incorporated therewith, are all very soluble in water, while in the latter case, the added materials are not soluble without the assistance of boiling heat and continued stirring.

When a paste instead of a hard cake is desired, the ground bean is mixed with some fluid soluble substance, such as treacle. Some of the inferior kinds, both cake and paste, as made by the lower class of manufacturers, are adulterated with hog's lard or sago, and some cheap colouring matter. When chocolate contains much starch it forms a pasty mass with boiling water.

The confectioners of Paris make a variety of sweetmeats of chocolate and sugar, which may be eaten without further preparation. This is the *chocolat de santé*. The perfumed sorts are consumed in enormous quantities in France, Italy, and Spain. In Britain, simple chocolate is preferred, and is, perhaps, the best substitute for tea and coffee. It sometimes produces a sense of heaviness in the stomach, resembling slight repletion, and occasioning head-ache. This generally arises from using too much chocolate in preparing the beverage. It is stated that the Spaniards do not

consider chocolate to be very nutritious: priests who are required to fast many hours before saying mass, are nevertheless allowed to drink chocolate.

Cocoa is a cheap substitute for chocolate, and is distinguished therefrom by containing a certain proportion of the shell or destitute. The nut as it leaves the grindstones is broken up, mixed with the shell and also with a quantity of farinaceous, saccharine, and other matters, all cheaper than the chocolate nut. If powdered cocoa is to be produced, the whole of these materials are kneaded together into a solid cake, which is dried and afterwards reduced to powder by pressing the cake up against a series of revolving cutting knives: the powder is then finished and is packed up in paper for sale. But if flake cocoa be

Fig. 570. FLAKE COCOA MILLS.

required, the powdered mixture is passed through 3 or 4 steel mills gradually increasing in fineness, the effect of which is so to combine and condense the materials, assisted by the presence of the oil of the nut, that they form into *flakes*, in which state they are ready for use. The flakes are best formed when the mills become slightly heated by the continued friction of the materials passing through them.

In the year 1849, there were imported into this country 7,769,234lbs. of cocoa, of which quantity 3,233,372lbs. were retained for home consumption, the remainder being re-exported. The amount of duty collected, was 16,644*l*. Before the alteration in the tariff in 1842, the duty on cocoa from British possessions was 2*d*., and from foreign countries 6*d*. per lb.; these were reduced to 1*d*. and 4*d*. On husks and shells the duty was ½*d*. and 1*d*.: these were left unaltered. On cocoa paste and chocolate which was 4*d*. per lb. from British possessions, and 4*s*. 4*d*. from foreign, the duty was reduced to 2*d*. and 6*d*.[1]

CHOKE-DAMP, a term given by the miners to carbonic acid gas, the product of the combustion of the small coal, dust, &c., after an explosion in a coal pit. See COAL.

CHROMIUM, a metal discovered by Vauquelin in 1797, and named from χρῶμα, *colour*, on account of its tendency to produce coloured compounds. Its two native combinations are the chromate of lead, and the chromite of iron. The latter, a compound of the oxides of chromium and iron, is found in the Shetland isles, Unst and Fetlar; near Portsoy in Banffshire, in the department of Var in France, (but this source is nearly exhausted;) in Silesia and Bohemia, and also at the Bare Hills near Baltimore, in Maryland. The chief use of this ore is for the production of chromate of potash.

Metallic chromium may be obtained by intensely heating the oxide with about one-tenth of its weight of powdered charcoal; but the reduction is imperfect. Dumas describes chromium as being like platinum in colour; it scratches glass, and takes a good polish. Its density is 5.9. When pure it is probably magnetic: its salts are distinctly so.

As many as five oxides of chromium have been enumerated. The *protoxide* ($Cr\,O$) does not appear to be a very staple compound. The *sesquioxide* (Cr_2O_3) or *green oxide* is formed by the decomposition of chromate of mercury by ignition: this yields a very pure oxide. There are various other methods of producing this oxide. (Professor Brande enumerates nine.) This oxide is infusible, and unchanged by heat, but the shades of its green colour are deeper in proportion to the temperature to which it has been exposed. When fused with borax and other vitrifiable substances, it confers on them a characteristic emerald green colour, and hence its use in porcelain and enamel painting. A *hydrate* of this oxide may be formed by precipitating it from its acid solutions by the caustic fixed alkalies. It falls as a bulky green powder, slightly soluble in excess of the alkali, but is thrown down on boiling the solution. Native sesquioxide of chromium has been found in the form of a green incrustation in the department of the Rhone in France. It is the colouring matter of the emerald, and occurs in a few other minerals, such as diallage and serpentine. It is associated with silica and alumina: the shades of green varying with the amount of the oxide; but the richest specimen does not contain more than 13 per cent. *Binoxide of chromium* ($Cr\,O_2$) is formed when nitrate of chromium is decomposed at a dull red heat. It is of a brown colour. *Peroxide of chromium* ($Cr\,O_3$) is an important and beautiful acid, the *chromic*. There are various methods of preparing it, but it may be stated that whenever oxide of chromium is strongly heated with an alkali in contact with air, oxygen is absorbed, and chromic acid generated. The acid nearly pure may be obtained by the following simple process described by Mr. Warington:—100 measures of a cold saturated solution of bichromate of potash are mixed with from 120 to 150 measures of concentrated sulphuric acid, (free from lead,) and the whole suffered to cool. The chromic acid crystallizes in brilliant crimson-red prisms. The mother liquor is poured off, and the crystals placed upon a thick flat tile of biscuit porcelain to drain, being closely covered by a glass or bell-jar, or another tile may be placed on the crystals, and the whole submitted to pressure for a considerable time. On removing the chromic acid it will be found to be dry, and with scarcely a trace of sulphuric acid.

(1) For the illustrations and much of the information in this article, as well as in the articles CHICORY and COFFEE, we are indebted to Messrs. Barry, of Type Street, London.

Chromic acid is of a beautiful red colour at the ordinary temperature, but it becomes almost black by being heated. Its solution is of a deep yellow brown; its taste sour and metallic; it tinges the skin yellow. At a red heat it gives out oxygen, and sesquioxide remains; it is acted on with energy by ammonia, and converted into oxide. It dissolves in alcohol, and the solution gradually deposits green oxide. It is a powerful oxidising and bleaching agent, yielding half its oxygen to oxidisable bodies, and being reduced thereby to sesquioxide.[1] Hence it can be successfully used in calico-printing, where the more powerful chlorine would be objectionable. Chromic acid is very deliquescent and soluble in water. The solution is decomposed by the sun's rays, and oxide thrown down. In combination with oxide of tin, this acid (or oxide of chromium) forms a pink colour used in porcelain painting. Chromic acid is said to be the colouring matter of the ruby.

The three most important compounds of chromic acid in the arts, are the *chromate* and *bichromate of potash*, and the *chromate of lead*. Chromate of potash (KO,CrO_3) is the source of all the preparations of chromium in the arts. It is made directly from the native chrome iron ore, by reducing the stone to powder, mixing it with one-fourth of nitre, and exposing the mixture to a strong heat during several hours. The soluble matter is then washed out, and the process is repeated until the ore is decomposed. The washings yield chromate of potash by evaporation. The crystals are of the same yellow colour as the solution. 100 parts of chromate of potash contain 48 of potash and 52 of chromic acid. This salt has a cool, bitter, and disagreeable taste. It is very soluble in boiling water. At 60°, 100 parts of water dissolve about 48 of the salt; or in other words, it is soluble in 2 parts water at 60°. Its colouring power is so great that 1 part gives colour to 40,000 parts of water. When heated to 400° it becomes crimson, but regains its yellow colour on cooling. As chromate of potash is isomorphous with sulphate of potash, the latter salt is sometimes used to adulterate the former. The adulteration may be detected by adding a few drops of nitric acid to the solution of the chromate, and then on testing with nitrate of baryta, an insoluble sulphate of baryta is thrown down.

When sulphuric acid in proper quantity is added to a solution of chromate of potash, one-half of the base is removed, and the neutral chromate is converted into bichromate ($KO,2CrO_3$). There is some difficulty in separating the sulphate from the bichromate, hence it is desirable to use nitric or acetic acid instead of sulphuric. Immense quantities of this salt are manufactured at Glasgow for the use of the calico-printers. It crystallizes by slow evaporation in beautiful red tabular crystals, derived from an oblique rhombic prism. It melts when heated; it is soluble in 10 parts of water at 60°, but is much more soluble in boiling water. The solution has an acid reaction. Solutions both of the chromate and bichromate of potash have powerful antiseptic properties; but they have an injurious action on the system when brought much in contact with the skin, causing painful sores which are difficult to heal. Paper impregnated with these salts and dried, forms excellent tinder. 100 parts of bichromate of potash contain 31.6 of potash, and 68.4 of chromic acid.

On mixing a solution of chromate or bichromate of potash with nitrate or acetate of lead, a brilliant yellow precipitate falls, which is chromate of lead (PbO,CrO_3), or *chrome yellow* of the painter. It consists in 100 parts of 68.29 oxide of lead, and 31.71 chromic acid. On boiling this compound with lime-water, one-half of the acid is withdrawn, and a sub-chromate of an orange red colour is left. The subchromate is also formed by adding chromate of lead to fused nitre, and then dissolving out the soluble salts with water. The product is crystalline, and in beauty of tint rivals vermilion. The yellow and orange chrome colours are fixed upon cloth by the alternate application of the two solutions, and in the latter case by passing the dyed stuff through boiling hot lime-water. Chromate of lead is insoluble in water, but soluble in nitric acid and in solution of potash. It forms, with solution of carbonate of potash, carbonate of lead and chromate of potash. With hydrochloric acid it forms chloride of lead and a hydrochloric solution of chromic acid. Heated in concentrated hydrochloric acid, chlorine is given off, and chloride of lead and a green solution containing chloride of chromium are formed. When this salt is heated its colour deepens. It fuses at a red heat, and gives off oxygen. A native chromate of lead has been found in the gold mine of Beresof in Siberia. A dichromate or subchromate of lead ($2PbO, CrO_3$), an insoluble scarlet-coloured powder, is also used with the former, both in oil and water colours, in dyeing and calico-printing. These salts are often adulterated with sulphate of lead and sulphate of lime.

A salt of chromic acid is recognised by its behaviour with solutions of baryta and lead; and also by its colour and capability of furnishing by deoxidation the green oxide of chromium.

CHRONOMETER. See Horology.

CHURN. See Butter.

CIDER. The expressed and fermented juice of apples, a liquor made in large quantities in England and Ireland, and in the north of France. The machinery employed is generally of a very rude kind. A large circular stone trough called a *chase*, receives the apples, which are crushed therein by the action of a heavy circular stone called a *runner*, turned by horse-power. The crushing is carried on till not only the apples but the very pips are broken. The pulp, called *must*, is then transferred to the cider-press, where it is subjected to heavy pressure between hair-cloths, or layers of reed-straw, and the cider exudes in the form of a thick brown juice, leaving only a dry residue between the hair-cloths. But this dry must is sometimes steeped in water and ground over again,

(1) If a few drops of absolute alcohol be allowed to fall on chromic acid, the latter is suddenly converted into sesquioxide with such a disengagement of heat as to kindle the alcohol.

from which a thin water-cider is produced. As the cider is pressed from the hair-cloths, it passes along a channel in the frame of the press into a flat tub called a *trin*, whence it is transferred at once into casks placed out of doors, or in a cool shed. In a few days it will ferment, the thicker portions subsiding, and the rest becoming clear and bright. It is then usually racked off, and the sediment strained through linen bags. If fermentation continues, and is in excess, the cider has to be racked off several times. If fermentation is too slow, and the liquor remain thick, isinglass or eggs stirred into it may clear it, but do not always have that effect. The total produce of cider and *perry* (the latter made in the same way from the pear) is estimated at from 150,000 to 160,000 barrels annually. The duty, which amounted to 10*s*. a barrel, was repealed in 1830.

CIGARS. See Tobacco.

CINNABAR, the sulphuret of mercury, and the principal ore of this metal. See Mercury.

CINNAMON, the bark of the cinnamon-tree, *Laurus cinnamomum*, a native of Ceylon. It also grows in Cochin China. In its natural state it attains the height of 20 or 30 feet, sending forth spreading branches clothed with thick foliage. The leaf somewhat resembles that of the bay, but is longer and narrower. The flowers bloom in January, and resemble in size and shape those of the lilac. These are followed by one-seeded berries of the shape of an acorn, but not so large as a common pea. This fruit yields, by being boiled, an oil, which cools into a wax-like substance, and is used for making candles; these emit an agreeable odour, and in the kingdom of Candy are reserved for the sole use of the court.

Cordiner in his history of Ceylon[1] states a number of interesting particulars respecting this tree. The cultivated trees are not allowed to rise higher than about 10 feet. When the trees first put forth their flame-coloured leaves and delicate blossoms, the effect is very beautiful. In 3 years after planting, each tree affords 1 shoot fit for cutting; at the 5th year, from 3 to 5 shoots; and after 8 years it yields as many as 10 branches of an inch in thickness, fit for cutting. From the ages of 10 to 12 years is the period of its greatest perfection; but its duration is not limited, as the root spreads and every year sends up new shoots or suckers. The tree is known to be in the best state when the bark separates easily from the wood, and the inside is covered with a mucilaginous juice, which it is necessary to remove. The shoots are cut when from half to three-quarters of an inch in thickness, and in lengths of from 2 to 3 feet. Each man is compelled to furnish a certain quantity of sticks, and having completed his task, he conveys his fragrant load to a shed, where the bark is stripped from the wood and the epidermis scraped off. During this process the diffused fragrance is said to be delightful, but in other parts of the plantation the peculiar smell of cinnamon cannot be distinguished unless the trees be violently shaken. The wood deprived of the bark has no smell, and is used as fuel. The cleansed bark is of a pale yellow colour, and of about the thickness of parchment. It is placed on mats to dry in the sun, when it curls up and acquires a darker tint. The smaller pieces are then put inside the larger, and the whole close together into the tubular form in which it is sold in the shops. When the rind or part forming the cinnamon is first taken from the tree, it is said to consist of an outer portion which tastes like common bark, and an inner portion which is very sweet and aromatic. In the course of drying, the oil of the inner portion, on which the flavour depends, is communicated to the whole, and the quality of the entire bark is said to depend upon the relative quantities of those portions of the bark. The cinnamon of Ceylon has the outer portion much thinner in proportion to the inner than the cassia[2] of other countries; and to that its higher pungency is attributed. According to McCulloch cinnamon is imported in bags or bales, weighing 92½lbs. each, and in stowing it black pepper is mixed with the bales to preserve the cinnamon. The best cinnamon is thin and rather pliable, of a light yellow colour, smooth and shining, with a splintery fracture, an agreeable, warm, aromatic flavour, and a mild sweetish taste; when chewed the pieces become soft and seem to melt in the mouth; it may be borne on the tongue without pain, and is not succeeded by any after taste. The cinnamon of Cochin China is preferred in China to that of Ceylon: the annual imports into Canton and other parts, vary from 250,000 to 300,000lbs. There are ten varieties of this species in the market: it is not cured like that of Ceylon by freeing it from the epidermis. In 1849 the quantity of cinnamon imported into the United Kingdom was, 758,812lbs., of which only 62,658lbs. were retained for home consumption. The gross amount of duty received was 953*l*. The duty by the new tariff is 6*d*. per lb. on foreign, and 3*d*. per lb. on the cinnamon of British possessions.

Oil of cinnamon was formerly obtained at Columbo by distilling with water the fragments of the cinnamon bark broken off in packing, and also the coarse cinnamon unfit for exportation. A very small quantity is contained in the bark, 300lbs. of which are required to yield 24 ounces of oil. At present there are two varieties of oil of cinnamon met with in commerce, of very unequal value, viz. that of China and that of Ceylon: the former is considered the best, but both are very impure. The pure oil may be extracted from them by adding cold, strong nitric acid: the crystalline matter which forms after the lapse of a few hours, separated and decomposed by water, yields pure oil of cinnamon. When the oil is made from the finest cinnamon its specific gravity is said to be greater than water, but from the coarse sort, less. In the former case fine cinnamon is crushed, infused twelve hours in a saturated solution

(1) Quoted, with additions, by Dr. Lankaster, in his work on "Vegetable Substances used for the Food of Man," (published in the Library of Entertaining Knowledge,) our chief authority in the early part of this article.

(2) The *laurus cassia* is chiefly brought from China: the bark and buds are known in commerce as *cassia lignea* and *cassia buds*, they have the same aroma, though in an inferior degree, as cinnamon, and are extensively substituted for it.

of common salt, and then the whole is subjected to rapid distillation. Water passes over, milky, from the presence of essential oil, which after a time separates and sinks to the bottom of the receiver. It is collected and left for a short time in contact with chloride of calcium. Like most of the volatile oils, it has a certain degree of solubility in water: it is highly fragrant, colourless or of a slight yellow tint, of an agreeable cinnamon odour, and of a pungent burning flavour. It contains according to Dumas $C_{18}H_8O_2$.

When the pure oil is exposed to the air it absorbs oxygen, and becomes converted into a mass of white crystalline matter, which is *hydrated cinnamic acid*. Cinnamic acid is found in Peruvian and Tolu balsams, associated with benzoic acid which it closely resembles, and certain oily and resinous substances. The radical of this acid has been named *cinnamyle;* it has not been isolated. The following is a list of cinnamyle compounds :—

Cinnamyle (symbol Ci)	$C_{18}H_7O_2$
Hydruret of cinnamyle; oil of cinnamon	$C_{18}H_7O_2 + H$
Oxide of cinnamyle; cinnamic acid	$C_{18}H_7O_2 + O$
Chloride of cinnamyle	$C_{18}H_7O_2 + Cl$.

CITRIC ACID, an acid common to many vegetables; it is abundant in lemon and in lime juice; it is also contained in currants, gooseberries, raspberries, and strawberries, and in the onion and potato. It is prepared by a few manufacturers on a very large scale for the use of calico-printers: it is also used in pharmacy. It is obtained chiefly from lemon and lime juice, a gallon of good lemon juice affording about 8 ounces of the crystallized acid, although as much as 12 ounces have been obtained from this quantity of juice. In preparing the acid, the juice is allowed to ferment a short time, for the purpose of separating mucilage and other impurities; the clear liquor is then saturated with chalk, added in small portions at a time, which forms with the citric acid an insoluble compound. This is washed with hot water, decomposed by the proper quantity of sulphuric acid diluted with water, and the filtered solution evaporated to a small bulk is left to crystallize.

The product is drained from the mother liquor, re-dissolved, digested with animal charcoal, and again concentrated to the point of crystallization. Citric acid forms colourless prismatic crystals, which have a pure and agreeable acid taste: they dissolve readily in water, but the solution becomes mouldy by long keeping. Citric acid is sometimes adulterated with tartaric acid, which may be detected by adding to the acid, dissolved in cold water, a solution of acetate of potash, which will throw down a white crystalline precipitate of bitartrate of potash (cream of tartar), if tartaric acid be present. Citric acid is distinguished from most of the other vegetable acids by its behaviour with lime-water: when citric acid is added to lime-water, the liquid remains clear till it is heated, and then becomes turbid, and deposits citrate of lime.

"Citric acid is tribasic: its formula, in the gently-dried and anhydrous silver-salt, is $C_{12}H_5O_{11}$. The hydrated acid crystallizes with two different quantities of water, assuming two different forms. The crystals which separate by spontaneous evaporation from a cold saturated solution contain $C_{12}H_5O_{11}, 3HO + 2HO$, the last being water of crystallization; while, on the other hand, those which are deposited from a hot solution contain but 4 equivalents of water altogether, 3 of which are basic. Citric acid is entirely decomposed when heated with sulphuric and nitric acids: the latter converts it into oxalic acid. Caustic potash at a high temperature resolves it into acetic and oxalic acids. The citrates are very numerous, the acid forming, like ordinary phosphoric acid, three classes of salts, which contain respectively 3 equivalents of a metallic oxide, 2 eqs. of oxide and 1 eq. of basic water, and 1 eq. oxide and 2 eqs. basic water, besides true sub-salts, in which the water of crystallization is perhaps replaced by a metallic oxide." [1]

CIVET, a substance used in perfumery, having a powerful scent, resembling musk and ambergris. It is obtained from the civets (*Viverra*), a genus of carnivorous animals, approaching nearest in their form and habits to the fox and the cat. But the distinctive character of the civets consists in an opening near the tail, leading into a double cavity of considerable size, furnished with glands for the secretion of the odorous substance. When the secretion is in excess, the animal frees itself from it by a contractile movement, which causes the civet to ooze from the bag. This is carefully collected and sold (not without adulteration with butter or oil, to increase its weight) at a very high price. These animals are carefully kept and tended in North Africa, for the sake of the perfume: they are also common in South America, and in the forests of Japan. Civet contains free ammonia, resin, fat, and extractiform matter, and a volatile oil to which its odoriferous properties are due. It is imported into England from the Brazils and from Guinea. When genuine, it is worth from 30 to 40 shillings an ounce.

CLAY, a compound, or perhaps only a mixture, of the two earths, alumina and silica, with water. Clay is an essential ingredient in all fertile soils. Its origin is thus explained by Mr. Fownes: "Silicates of alumina enter into the composition of a number of crystallized minerals, among which felspar occupies, by reason of its abundant occurrence, a prominent place. Granite, porphyry, trachyte, and other ancient unstratified rocks, consist in great part of this mineral, which, under peculiar circumstances, by no means well understood, suffers complete decomposition, being converted into a soft friable mass of earthy matter. This is the origin of clay: the change itself is seen in great perfection in certain districts of Devonshire and Cornwall; the felspar of the fine white granite of those localities being often disintegrated to an extraordinary depth, and the rock altered to a substance resembling soft mortar. By washing, this finely-divided matter is separated from the quartz and mica, and the milk-like liquid being collected in tanks and suffered to stand, deposits the suspended clay, which is dried, first in the air, and afterwards in a stove,

(1) Fownes, "Manual of Chemistry."

and employed in the manufacture of porcelain.[1] The composition assigned to unaltered felspar is Al_2O_3, $3SiO_3+KO,SiO_3$, or alum, having silicic acid in the place of sulphuric. The exact nature of the change by which it passes into porcelain clay is unknown, although it evidently consists in the abstraction of silica and alkali. When the decomposing rock contains oxide of iron, the clay produced is coloured. The different varieties of shale and slate result from the alteration of ancient clay beds, apparently, in many instances, by the infiltration of water holding silica in solution: the dark appearance of some of these deposits is due to bituminous matter." [See ALUM and ALUMINA.]

According to Gmelin, nearly all pure clay consists of $Al_2O_3, 2SiO_2+2Aq.$; but in nature it is generally found mixed with carbonate of lime, magnesia, and protoxide of iron, which cause it to effervesce with acids; it also contains manganese, finely-divided quartz, felspar, mica, organic matter, &c., all of which modify its properties and applications to a considerable extent. The presence of potash, lime, sesquioxide of iron, &c., renders it more fusible. Pure clay is soft, more or less unctuous to the touch, white, and opaque, and emits a characteristic odour when breathed upon. This odour has been referred to ammonia contained in the clay. Clay is converted by water into a doughy mass, of various degrees of tenacity, but it loses this quality on drying. When rapidly heated it cracks in every direction, but when slowly heated it parts with its water at a temperature below redness; and at the same time diminishes in bulk: if heated to redness, it continues porous, and may be saturated with water; but it no longer falls to pieces when put into water. The stronger the heat to which it is exposed, the more hard, dense, and sonorous does the clay become. At a very high temperature, the pores contract; but the specific gravity of the clay, taken in a state of powder, increases only up to a dull red heat: at a higher temperature it again diminishes. Pure clay does not fuse in the most powerful blast-furnaces; it becomes, however, soft enough to be bent for pipe-stems. Clay dissolves with difficulty in borax, forming a transparent glass; with phosphate of soda it forms a glass which is transparent and white while hot, and becomes opalescent as it cools, a skeleton of silica being also separated; with carbonate of soda it forms a green glass, if iron be also present; ignited with solution of cobalt it generally assumes a blue colour. Clay does not dissolve in dilute muriatic or nitric acid. The action of sulphuric acid has been already referred to in our article on ALUM.

The property which clay possesses of being converted by heat into a strong mass, which no longer falls to pieces in water, is taken advantage of in the manufacture of bricks and vessels of various kinds. To diminish its contraction in drying and burning, it is generally mixed with a considerable quantity of quartz, sand, or with powder of burnt clay. The smaller the amount of lime, potash, &c., present in the clay, the higher is the temperature which it sustains without fusing, and the more dense and solid is the baked mass obtained. But since it always remains porous, it is generally covered with a glaze consisting of an easily fusible glass, usually containing oxide of lead. For stoneware and porcelain a mixture is used of very infusible clay and fine quartz sand, with a certain portion of gypsum or felspar. The lime present in the former, or the potash in the latter, gives rise at a high temperature to incipient fusion and softening of the mass, by which means its porosity is in a great measure diminished.[2] [See POTTERY and PORCELAIN.]

The following are some of the common varieties of clay:—1. *Pipe-clay.* This is of a greyish white colour, with an earthy fracture, and a smooth greasy feel; it adheres to the tongue, and is very plastic, tenacious and infusible. When burnt it is of a cream colour, and is used for tobacco-pipes and white pottery. It is found near Poole in Dorsetshire. 2. *Potter's clay* is of various colours, chiefly reddish or grey, and becomes red when heated. Mixed with sand it is formed into bricks and tiles. It is found in Hampshire, Berkshire, and Devonshire, and is forwarded from thence in large quantities to the Staffordshire Potteries. 3. *Stourbridge clay* resembles potter's clay to a certain extent, but is far more refractory in the fire. It is of a dark colour, owing probably to the presence of carbonaceous matter. It is extensively used in making crucibles, glass pots, &c. 4. *Brick-clay* or *loam* is found in abundance on the London clay, and frequently rests on an interposed bed of sand. It varies greatly in appearance, texture and composition; its colour depending on the proportion of oxide of iron contained in it. 5. *London clay* is a very extensive deposit of a bluish clay. Near the surface, however, it has often the usual clay colour. It extends over the greater part of Middlesex, the whole of Essex and Suffolk, and part of Norfolk. It frequently rises almost to the surface. The lower beds are sometimes yellowish, white, or variegated. This clay contains organic remains. 6. *Plastic clay* skirts the London clay within the London chalk basin, and it appears also at the Isle of Wight. This formation comprises a variable number of sand, clay, and pebble beds, alternating irregularly, and lying immediately upon the chalk. The sand-beds of this formation supply the deep wells in and about London with soft water. [See ARTESIAN WELLS.]

Brongniart in his "Traité des Arts Céramiques ou des Poteries," (Paris, 1844,) has given an elaborate list of clays used in the arts in different parts of the world. The number of specimens cited is 167. Their physical and chemical characters, composition, locality, and application are also given. We shall refer more particularly to this work in the article POTTERY, &c.

CLOCK. See HOROLOGY.

CLOVES, the unopened flowers of the clove-tree,

(1) This forms the *Kaolin*, to which the porcelain of China owes its celebrity.

(2) Gmelin's "Handbook of Chemistry." Translated by Henry Watts. Vol. III. London. 1849. Published by the Cavendish Society.

(*Caryophyllus aromaticus*,) a native of the Moluccas, aromatic in its bark, root, leaves, and flowers, but with an insipid fruit resembling a small plum. Vigorous trees yield 10 or 12 pounds weight of flowers annually. The largest trees (which are as much as 8 feet in diameter) sometimes yield 50 or 60 pounds weight. Cloves as imported are nearly black, of a powerful fragrance, and hot acrid taste. They derive their name from *clou*, the French for a *nail*, owing to the resemblance they are thought to bear in their dried state to small nails. They are imported from the Dutch settlements, the best in chests, the inferior sort in bags. The Dutch have exclusive possession of the Moluccas or Clove islands, and by a short-sighted policy, they have limited the cultivation of these trees to one island, Amboyna, the seat of their power, and send an annual fleet to visit the other islands, and suppress the growth of cloves, which spring up like weeds in the soil. This arises from a jealous apprehension lest the natives should interfere with their policy, which is to derive a large profit from a small trade, instead of a moderate profit from a more extended and beneficial one. Now that the duty has been almost taken off cloves, (being reduced to sixpence a pound,) the consumption has considerably increased, but not in the proportion which it would have done under a more liberal policy. The price of cloves in the London market exclusive of the duty varies from 1*s*. to 2*s*. 2*d*. per lb. In 1849, 274,712 lbs. of cloves were imported; 134,881 lbs. entered for home consumption, and 3,542*l*. paid as duty.

An essential oil is obtained from cloves by repeated distillation, and it is a common trick to mix cloves thus deprived of their oil with other cloves. They may easily be detected by being lighter coloured, shrivelled, and without the knob. Oil of cloves is hot and fiery. It is used in medicine as a stomachic, and to render some medicines safer and more agreeable. Two drops form a dose.

The sp. gr. of oil of cloves varies between 1.05 and 1.06, so that it is heavier than water, a circumstance which affords an easy test of its purity; for as this oil is often adulterated with olive and other light oils, all that is necessary is to pour the suspected oil into cold water, when the oil of cloves will sink, and the oil used as an adulterant will float on the surface. It appears, however, from recent researches that oil of cloves is composed of two distinct oils, one of which has a sp. gr. of 0.918, and is incapable of combining with bases; and the other possessing acid characters has a sp. gr. of 1.079. The indifferent oil is a hydrocarbon of the cloves, $C_{10}\,H_8$. The acid oil has the formula $C_{24}\,H_{15}\,O_5$. It has been named *Eugenic acid*. It is a transparent, colourless, oily liquid, with a strong odour of cloves, and a burning aromatic flavour. It forms a class of salts named *eugenates*, which have the taste and smell of the acid.

COACH. See Wheel Carriages.

COAL. There are several varieties of coal, all of which appear to have been formed by the action of certain chemical forces on wood or other vegetable matter; but these varieties may for the most part be arranged into two groups, the one containing no bitumen, and the other distinguished by the presence of that substance. In the first variety, or that without bitumen, is *anthracite*, also called *glance coal* and *stone coal*. It is compact and hard, with a high lustre, and is often iridescent. It takes a high polish, on which account it is often made into inkstands, boxes, and ornamental articles. Its specific gravity varies from 1.3 to 1.75. It contains from 80 to 90 per cent. of carbon, with from 4 to 7 of water. In some varieties of anthracite bitumen is present, in which case it burns with a considerable flame. Indeed, anthracite passes gradually into bituminous coal, which varies greatly according to the amount of bitumen. The following are recognised varieties. *Caking* or *pitching coal* breaks into small pieces when heated, but on raising the heat they unite or *cake* into a solid mass. Its colour is velvet or greyish black. It burns with a lively yellow flame, but requires frequent stirring to prevent it from caking and so clogging the fire. *Cherry coal* resembles caking coal, but does not soften and cake: it is very brittle, and burns with a clear yellow flame. The *splint* or hard coal of the Glasgow coal beds is harder than cherry coal. *Cannel* or *candle coal* burns readily without melting, and has hence been used as *candles*, whence the name. It is of compact and even texture, little lustre, and breaks with a large conchoidal fracture. It is sometimes made into snuff-boxes, and similar articles. *Brown coal, wood coal*, and *lignite*, are imperfect varieties of coal, usually of a brownish black colour, and retaining the structure of the original wood, and burning with an empyreumatic odour. The substance termed *jet* resembles cannel coal, but is harder, of a deeper black colour, and higher lustre. It takes a brilliant polish, and is sometimes set in jewelry.

The following is a sketch of Liebig's views of the chemical processes which attend the formation of coal from wood. When wood is exposed to air and moisture it suffers decay or eremacausis: it moulders and becomes gradually converted into a dark brown or black powder, called *mould* or *humus*. The longer the process has been continued, the greater is the proportion of carbon in the residue. Thus oak wood is composed of $C_{36}\,H_{22}\,O_{22}$, and one specimen of oak humus was found to contain $C_{35}\,H_{20}\,O_{20}$, and another $C_{34}\,H_{18}\,O_{18}$; showing that for every two equivalents of hydrogen oxidized by the air, one equivalent of carbonic acid had been separated. If the decay were to continue until all the hydrogen had been separated, wood, consisting of $C_{36}\,H_{22}\,O_{22}$, would leave only C_{25}; but this final result does not usually occur, because the excess of carbon retains the last portions of hydrogen with an increasing affinity as the amount of hydrogen diminishes.

When wood is decomposed by the action of water, air being absent, the process is more properly *mouldering*, for in eremacausis or decay oxygen is the active agent. In mouldering, the access of oxygen is very limited, and the results are different from those of decay. The elements of water together with some

oxygen are taken up, and carbonic acid escapes. Thus when oak-wood was decomposed by lying under water, a white mouldered matter was formed containing $C_{33}H_{27}O_{24}$, and derived from oak-wood, $C_{36}H_{22}O_{22}$, by the addition of $5HO+O_3$ and the subtraction of $3CO_2$. Mouldered beech yielded $C_{33}H_{25}O_{24}$, which may be similarly accounted for. *Wood coal* or *brown coal* has been produced by a similar action. A pure specimen of wood-coal from Laubach contained $C_{33}H_{21}O_{16}$; that is, a greater proportion of carbon and hydrogen and a smaller proportion of oxygen than wood. If wood were to lose 3 atoms of carbonic acid and 1 atom of hydrogen, such a wood-coal would be the result:

For if from wood . . . $=C_{36}\ H_{22}\ O_{22}$ we take
1 at. hydrogen, and 3 at. Carbonic acid $=C_3\ H\ \ O_6$

there will be left wood coal ....$=C_{33}\ H_{21}\ O_{16}$.

In the formation of wood-coal the essential change seems to be the separation of carbonic acid from its elements, while a portion of hydrogen is removed by oxidation, owing to the limited access of air. The separation of carbonic acid seems still to go on even in the deepest beds of brown coal, and is probably the source of the acidulous springs found near such beds, and also of choke-damp in mines. When near the surface, the proportion of hydrogen in wood-coal is always less, owing to the action of the air, by the oxygen of which the hydrogen is removed.

Mineral coal appears to be produced by a long-continued decomposition of wood or of wood-coal, by which carbonic acid, water and carburetted hydrogen are separated. Splint coal and cannel coal are both $C_{24}H_{13}O$, which may be thus derived from wood:—

3 at. Carburetted hydrogen $C_3\ H_6$
3 at. Water .... $H_3\ O_3$
9 at. Carbonic acid .... $C_9\ \ O_{18}$
} $C_{36}\ H_{22}\ O_{22}$=Wood
$C_{12}\ H_9\ O_{21}$

$C_{24}\ H_{13}\ O$= { Mineral coal.

Caking coal is $C_{20}H_9O$, or cannel coal *minus* olefiant gas, C_4H_4. This explains the occurrence of fire-damp in coal mines; whereas in mines of wood-coal carbonic acid or choke-damp alone occurs. The occurrence of fire-damp proves that changes are constantly occurring in the beds of coal. When the whole of the hydrogen is removed in the form of carburetted hydrogen, the residue must be *anthracite*, which is nearly pure carbon.

By distilling coal with water, oily and resinous matters have been obtained. These oils and naphtha may be formed out of the elements of the carbonic acid and carburetted hydrogen separated from the wood during its conversion into coal; but if the wood had been originally of the pine tribe, the resin and oil of turpentine may have been originally present in it.[1]

Mr. Hutton has given decisive proof of the vegetable origin of coal, by submitting to microscopic examination an extensive series of slices taken from the several varieties of coal found at Newcastle and the contiguous district. He considers this coal to be of three kinds; the first, which is the greatest in quantity and the best in quality, is the rich *caking* coal, so generally esteemed; the second is *cannel* or *parrot* coal (*splint* coal of the miners); and the third, *slate* coal, consisting of the two former arranged in their alternate layers with a slaty structure. In these varieties, taken indiscriminately, more or less of the vegetable texture could always be discovered, thereby affording the fullest evidence of the vegetable origin of coal. Each of these three kinds of coal, besides the fine distinct reticulation of the original vegetable texture, exhibits other cells which are filled with a light wine-yellow-coloured matter, apparently of a bituminous nature, and which is so volatile as to be entirely expelled by heat before any change is effected in the other constituents of the coal. The number and appearance of these cells vary with each variety of coal. In caking coal, the cells are comparatively few, and those which do exist are highly elongated. Their original form the author believes to have been circular, and he attributes their present figure to the distension of gas confined in a somewhat yielding material subject to perpendicular pressure. In the finest portions of this coal, where the crystalline structure, as indicated by the rhomboidal form of its fragments, is most developed, the cells are completely obliterated. In such parts the texture is uniform and compact: the crystalline arrangement indicates a more perfect union of the constituents, and a more entire destruction of the original texture of the plant. The slate coal contains two kinds of cells, both of which are filled with yellow bituminous matter. One kind is that already noticed in caking coal: while the other kind of cells constitutes groups of smaller cells of an elongated circular figure. In those varieties which go under the name of cannel, parrot, and splint coal, the crystalline structure, so conspicuous in fine caking coal, is wholly wanting, the first kind of cells is rarely seen, and the whole surface displays an almost uniform series of the second class of cells, filled with bituminous matter, and separated from each other by their fibrous divisions. Mr. Hutton considers it highly probable that these cells are derived from the reticular texture of the parent plant, rounded and confused by the enormous pressure to which the vegetable matter has been subject. The author states that though the crystalline and uncrystalline, or perfectly and imperfectly developed varieties of coal generally occur in distinct strata, yet it is easy to find specimens which in the compass of a single square inch contain both varieties. From this fact, as also from the exact similarity of position which they occupy in the mine, the differences in different varieties of coal are ascribed to original difference in the plants from which they are derived.[2]

Geological examinations of coal-fields have also afforded abundant evidence of the vegetable origin of coal, although the manner in which the *carboniferous*

(1) Turner's "Chemistry." Eighth Edition. Edited by Liebig and Gregory. London, 1847. "Chemistry in its application to Agriculture," &c. by Justus Liebig, &c. 4th Edition. London, 1847.

(2) "Proceedings of the Geological Society of London." No. 29. 1832—1833.

strata (as the *coal-measures*, or assemblage of rocks which include coal, are termed) have been deposited is by no means agreed upon. Some geologists suppose that the coal-measures were originally peat-bogs, and that the successive layers were occasioned by repeated subsidences of the land; others contend that the vegetable matter originated from *rafts*, like those of the Mississippi, which floated out to sea and there became engulfed; a third opinion is, that they were formed in vast inland seas or lakes, the successive beds of vegetable matter being supplied by periodical land-floods. All these causes may have been in operation in the formation of coal, but, however deposited, the coal is always accompanied by a thick bed of clay beneath every layer; and it is, moreover, a remarkable fact, that a common plant of the coal strata, named *Stigmaria*, invariably occurs, more or less abundantly, in this bed of underclay, although it is rarely to be met with in the coal or shale above.

If we trace the series of which a coal-field is composed, beginning with the lowermost stratum, we have:—1, the *underclay*, a tough, argillaceous substance, which changes upon drying into a grey, friable earth: it is sometimes black, from the presence of carbonaceous matter: it contains innumerable stems of Stigmaria, as already noticed; 2, then comes the coal, in which the external forms of plants, &c. are obliterated by the process of bituminization, although the internal structure remains; 3, the *roof*, or upper bed, which generally consists of slaty clay, abounding in leaves, trunks, stems, branches, and fruits,[1] and often containing layers of ironstone nodules, in which leaves, insects, crustacea, &c. are imbedded. Interstratified with the shale, finely-laminated clay, micaceous sand, grit and pebbles of limestone, granite, sandstone, and other rocks often occur. In fact, this bed appears to be an accumulation of drifted materials, mingled with the dense foliage and stems of a prostrate forest. "These phenomena," says Dr. Mantell, "may be explained by supposing the inundation of a thickly-wooded plain by an irruption of the sea, or of a vast inland lake, occasioned by the sudden removal of some barrier, or by a subsidence of the tract of country on which the forest grew. But when we find an accumulation of strata, in which triple deposits of this kind are repeated some thirty or forty times through a thickness of many thousand feet, a satisfactory solution of the problem is very difficult. Not only subsidence after subsidence must have taken place, but the first submergence have been followed by an elevation of the land—another soil fit for the growth of forest trees been produced—another generation of vegetables of precisely the same species and genera have sprung up, and arrived at maturity—and then another subsidence, and another accumulation of drift. And these oscillations in the relative level of the sea and land must have gone on uninterruptedly, through a long period of time, not in one district or country only, but all over the world, and during the same geological period."[2]

It will be understood from the preceding details that the series of rocks which constitute the coal-measures consists of beds of sandstone, shale, clay, and coal, lying one above another in repeated alternations to a great depth. The strata of coal, technically called *seams*, are very thin compared with the other associated beds. Although they extend under large tracts of country, they are often only a few inches thick, seldom more than 6 or 8 feet, except one seam in Staffordshire, which is 30 feet thick, but this must be regarded as a collection of minor seams nearly in contact. Under this series is the mountain limestone, forming various calcareous strata of variable thickness, sometimes exceeding 900 feet. This limestone rests on a bed of old red sandstone, varying in thickness from 200 to 2,000 feet. The term *coal formation* sometimes includes these two great series of strata, although, in general, the coal-measures lie above them, the lowest coal seam commonly resting on the mountain limestone.

The various deposits which form the coal-measures do not occur in regular horizontal unbroken planes, as might be supposed. There is no doubt that when first deposited they were in this condition, but this horizontal position has at various times been disturbed by some upheaving force from below, whereby the coal-measures have, in many districts, been made to assume the shape of a huge trough or *basin*, rising on all sides from a central point, the sides of the basin being composed of sandstone or limestone, and the middle filled up by strata superior to the coal-measures, viz. magnesian limestone, and new red sandstone. This will be better understood by referring to the diagram, Fig. 571, which represents a section across a coal-field, such as would result from making a deep perpendicular cut in the ground, and removing all the strata on one side; we should then see a wall exposed like a vertical cliff on the sea-shore.

Now it follows from the arrangement of these coal-basins, that the edge or boundary line of each stratum must appear at the surface somewhat like the concentric layers of an onion cut in two. This "coming to the day," or appearance of the coal at the surface of the ground, is called the *basset* or *outcrop*, and serves to determine the outer form or side of the basin. Coal-basins are generally elliptical in shape, but they are sometimes nearly circular and very often eccentric, being much greater in length than in breadth. Thus the great South Welsh coal-field, which comprises an area of upwards of 900 square miles, is in the form of a long-necked flask. In many cases one side of the basin upon the narrow diameter inclines more, or has a much greater *dip* than the other, whereby the trough or lower part of the basin is thrown much nearer to one side than the other. Hence it is

(1) Dr. Buckland, in his "Bridgewater Treatise," thus refers to the coal deposits of Bohemia:—"The most elaborate imitation of living foliage upon the painted ceilings of Italian palaces, bears no comparison with the beauteous proportions of extinct vegetable forms with which the galleries of these instructive coal-mines are overhung. The roof is covered, as with a canopy of gorgeous tapestry, enriched with festoons of most graceful foliage, flung in wild irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black colour of these vegetables with the light ground-work of the rock to which they are attached."

(2) "Medals of Creation; or, First Lessons in Geology, &c;" by Dr. Mantell. 2 Vols. London: 1844.

evident that in a perfect basin all the strata regularly crop out, and meet the surface in every point of its boundary. Few coal-fields are, however, thus circumscribed, by the outcropping of older strata. The two great fields of Northumberland and South Wales are bounded (the one on the east and the other on the south) by the sea, so that they are, strictly, only half basins. The Leicester and Warwickshire field has none of the characters of a basin, being surrounded on all sides by overlying strata, under which the coal-measures dip lower and lower, till they become too deep to be profitably worked: thus they have no outcrop, and their extent is unknown; but they probably extend under the surrounding new red sandstone into the Lancashire and other fields. (See Fig. 571, B.)

The internal upheaving force, whatever it may have been, which converted the horizontal strata into basin-shaped arrangements, probably produced at the same time certain fissures or fractures often nearly vertical, and stretching through the whole mass. (See Fig. 572.)

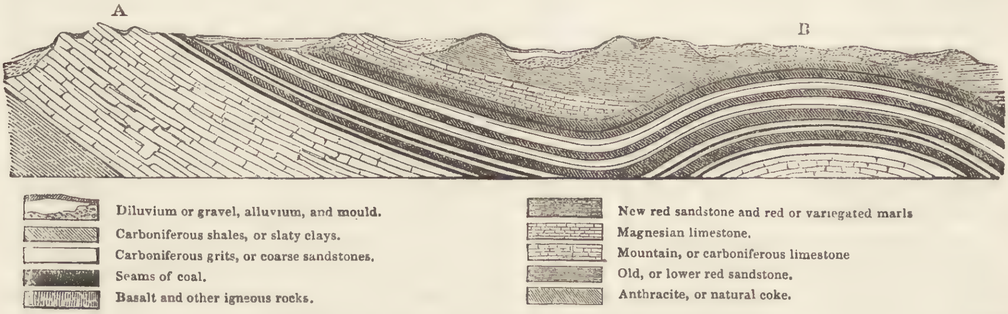
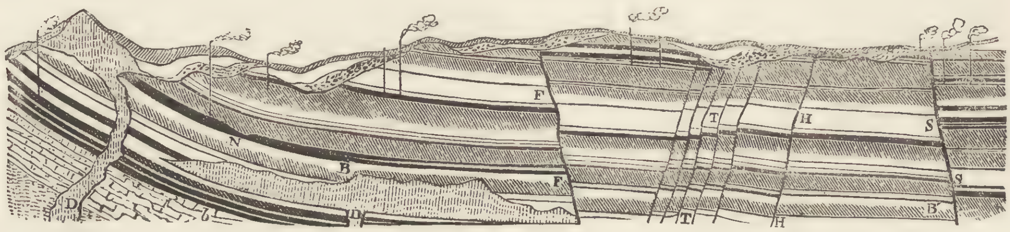


Fig. 571. SECTION OF THE GENERAL FEATURES OF COAL FIELDS.



D D, Whin Dykes; F F, S S, Faults or Slip Dykes; T T, Troubles; H, Hitch or Slip; *b* and B B', Bands; N, Nip or Baulk.

Fig. 572. ENLARGED SECTION OF THE ACCIDENTAL FEATURES OF COAL FIELDS.

These rents are of great importance to the miner, and may be beneficial to him, or not, according to circumstances. They are called *dykes*, because they divide the seams or bands of coal into *fields*, and are *up-throw* or *down-throw* dykes, according as the edge of the strata appears to an observer to be higher or lower in regard to his own position. They are also called *shifts*, as the miners consider that they have *shifted* the strata on their sides; but the common term is *faults* or *troubles*, from their *troubling* or putting to *fault* the pitmen.

Some of these dislocations of strata are so considerable as to obtain a place in geological maps. In the Northumberland and Durham coal-field, the most remarkable is called the *Main* or *Great Dyke*, or *Ninety-Fathom Dyke*, in which the beds on the north side are *ninety fathoms* lower than those on the south side of this dyke. The width is variable, in some places not great, but in Montague Colliery it is 22 yards wide, and is filled with hard and soft sandstone. Two other dykes branch off from the south side of this dyke, one to the south-east, which is 20 yards broad, and the other to the south-west, which, from its breadth, is called the *Seventy-Yard Dyke*. It is filled with sandstone, and intersects the upper seam of coal, which, however, does not appear to be thrown out of its level by the interruption. A slip dyke of less thickness than the workable seams, and not disturbing their continuity, is called a *hitch*, as at H, Fig. 572.

Other dykes, called *whin-dykes*, contain basalt, toadstone, and other rocks of igneous origin. Such dykes may, or may not be *slip* dykes, or such as cause a shifting of level in the adjacent beds. Thus those at D D, Fig. 572, are not accompanied by any slip. In approaching within a few yards of these once molten streams, the operation of fire is evident in the conversion of loose grits into compact quartz, and of clay or shale into slate and porcelain jasper, while the coal-seams are diminished in thickness and completely charred, or converted into blind-coal, anthracite cinders, sooty ashes, or in some cases coke, as perfect as that obtained from a coke oven. When basaltic or other igneous dykes reach the surface, or what was the surface at the time of their protrusion, their matter is either heaped up so as to form a hill, as in D, to the left of Fig. 572, or spread out into undulating masses, as occurs with the other dyke, D, in the same figure, or sometimes into extensive strata, destroying a vast extent of coal, or converting it into anthracite, as in the Ayrshire field.

It will readily be supposed that dykes are a frequent source of difficulty and expense, by throwing the seams out of their levels and filling the mines with water

and inflammable gas, whereby many fatal accidents arise. On the other hand, dykes and faults have their advantages; for when they are filled, as is often the case, with stiff clay, numerous springs of water are dammed up, and brought to the surface, instead of being poured into the mine. By means, also, of these dykes, valuable beds of coal are preserved within the field which would otherwise have cropped out and been lost. Thus the general depression between the faults F F and T T brings in two thick seams, which would not otherwise occur in this part of the field, as they belong to a higher level. Several valuable beds of coal near the main dyke would not have been available out for the general depression of the beds occasioned by that chasm.

Among the other accidental features of coal-fields may be mentioned *bands*, or thin strata of grit or shale in the heart of a coal-seam, and from a scarcely perceptible origin, as B, Fig. 572, gradually thickening, until, at a distance of perhaps many miles, they entirely usurp the place of the coal, or reduce a thick and valuable seam to a thin and useless one. A sudden local thinning of the seam by an excrescence from the roof or floor, as at N, is called a nip: this, however, is of rare occurrence.

Such are the general features of coal-measures. Mineral coal is widely distributed over the world. It constitutes the most important of the mineral treasures of Great Britain. It is found in France, Spain, Portugal, Belgium, Germany, Austria, Sweden, Poland, and Russia. It is abundant in some parts of India, China, Madagascar, Van Diemen's Land, Borneo and the other East India Islands, New Holland, and at Conception in Chili. But the most extensive known deposits are in the United States of America, where there are four great areas occupied by this formation. One of them commences on the north in Pennsylvania and south-eastern Ohio, and sweeping south over western Virginia and eastern Kentucky and Tennessee to the west of the Apalachians, it continues to Alabama, near Tuscalôosa. It has been estimated to cover 63,000 square miles. A second coal area (the Illinois) lies adjoining the Mississippi, and covers the larger part of Illinois, the western part of Indiana, and a small north-west part of Kentucky: it is but little smaller than the preceding. A third occupies a portion of Missouri, west of the Mississippi. A fourth covers the central portion of Michigan. There is, also, a small coal region in Rhode Island. Beyond the limits of the United States, on the north-east, commences a sixth coal area, that of Nova Scotia and New Brunswick, which covers 10,000 square miles. At Cape Breton is still another coal-field.[1]

The coal measures of Great Britain are variously dispersed in the midland, northern, and western portions of South Britain, and in a broad belt of country which traverses the centre of Scotland, from the shores of Ayrshire to those of the Frith of Forth. There are, also, some coal tracts of far inferior importance in Ireland.

The Table on the next page will give the reader a tolerably complete idea of the value of the coal of the British Islands. Commencing with the first in the list, the coal-pits on the eastern side of the island occupy a large portion of the counties of Durham and Northumberland, and are the most important of all pits which are wrought for the sale of coal. This great tract supplies not only the whole of those counties, the North Riding of Yorkshire, and the contiguous Scottish counties; but the whole of the eastern and southern coasts of England, as far as Cornwall, including the metropolis itself, and the great south-eastern region, into which the sales of the inland coal districts do not penetrate, on account of the greater cost of land carriage, and the want of canals. There is also an extensive export to foreign parts. This important region is sometimes divided into two districts, that of *South Durham*, south of the river Wear, and that of *North Durham* and *Northumberland*, comprising the rest of the field. 2. In the Cumberland coal-field, the pits are wrought only for sale, for the purpose of supplying the counties of Cumberland and Westmoreland, and for shipment chiefly at Whitehaven to Ireland, and the opposite shores of Scotland. In the West Riding of Yorkshire, the coal-pits supply extensive iron-works, and they also furnish fuel to a great part of Yorkshire, except the coast, and make some shipments down the Humber for London. 3. The coal-fields of Lancashire extend southward into the eastern part of Cheshire, and are worked to an enormous extent for the supply of the manufactures congregated in their neighbourhood; but there is no manufacture of iron from native ores in this district, or only to a very small extent. On the eastern border of *North Wales*, in Denbigh and Flint, bordering upon Cheshire, there are iron-works, and the coal-field supplies with fuel nearly the whole of North Wales, and a large portion of Cheshire and Shropshire. In North Staffordshire, besides the coal-field of the potteries, in which there are extensive iron-works at Kidscrew, there is a smaller tract contiguous to the town of Cheadle. 4. In the vale of the Trent, between Nottingham and Derby, commences the great coal-field of Derbyshire and Yorkshire, which extends hence northward, and of which the southern or Derbyshire portion occupies the eastern side of that county, and extends at one extremity into Nottinghamshire. Besides supplying with fuel a vast surrounding region, especially to the east and south in the counties of Leicester, Nottingham, and Lincoln, it has a considerable home consumption in iron-works. 5. 6. The most important coal-field in the midland counties is that of *South Staffordshire*, which, lying to the west and north of Birmingham, is remarkable for the extent to which its vast beds are worked, as well for the purpose of smelting the iron ores, which are raised from strata interspersed among the coal strata, as for the consumption of the neighbouring populous towns which are the seat of the metal manufactures, and for an extensive

(1) "Dana, Manual of Mineralogy." Newhaven: 1848. The reader who desires to study the subject of coal with reference to its geographical, geological, and commercial distribution, &c. is referred to the "Statistics of Coal," by R. C. Taylor, F.G.S. &c. London and Philadelphia: 1848.

"land sale," as the supply of the surrounding country with fuel is designated; the country southward, where canals extend as far as the Thames, being in great part supplied from this region. The *Shropshire* district of Coalbrookdale, lying midway between Wolverhampton and Shrewsbury, though much smaller in extent, is also the seat of great iron-works, and is the source of a supply of fuel for a great part of the vale of the Severn, and the country to the west of it, to the borders of Wales. The *Warwickshire* coal-field occupies a large tract on the north-eastern verge of that county, from Coventry to

TABLE OF THE PRINCIPAL COAL-FIELDS OF THE BRITISH ISLANDS.

	Estimated workable area in acres.	Number of workable seams.	Estimated total thickness of workable coal in feet.	Thickest bed in feet.	Thickness of coal-bearing measures in feet.
1. *Northumberland and Durham district.*					
Newcastle coal-field	500,000	18	80	7	
2. *Cumberland and Westmoreland, and West Riding of Yorkshire.*					
Whitehaven and Akerton	80,000	7		8	2,000
Appleby (3 basins)	17,000				
Sebergham (Cumberland)	?	1	3	3	
Kirkby Lonsdale	2,500	4	17	9	
3. *Lancashire, Flintshire, and North Staffordshire.*					
Lancashire coal-field	380,000	75	150	10	6,000
Flintshire	120,000	5	39	9	200
Pottery, North Staffordshire	40,000	24	38	10	
Cheadle, ditto	10,000				
4. *Yorkshire, Nottinghamshire, Derbyshire.*					
Great Yorkshire coal-field	650,000	12	32	10	
Darley Moor, Derbyshire } Shirley Moor, ditto }	1,500				
5. *Shropshire and Worcestershire.*					
Colebrook Dale, Shropshire	21,000	17	40		
Shrewsbury, ditto	16,000	3			
Brown Clee-hill, ditto	1,300	3			
Titterstone Clee-hill, ditto	5,000				
Lickey-hill, Worcestershire	650	?	?	?	
Bewdley ditto	45,000	?			
6. *South Staffordshire.*					
Dudley and Wolverhampton	65,000	11	67	40	1,000
7. *Warwickshire and Leicestershire.*					
Nuneaton	40,000	9	30	15	
Ashby-de-la-Zouch	40,000	5	33	21	
8. *Somersetshire and Gloucestershire.*					
Bristol	130,000	50	90		
Forest of Dean	36,000	17	37		
Newent, Gloucestershire	1,500	4	15	7	
9. *South-Welsh coal-field*	600,000	30	100	9	12,000
10. *Scottish coal-fields.*					
Clyde Valley . . . . } Lanarkshire . . . . } South of Scotland, several small areas }	1,000,000	84	200?	13	6,000
Mid-Lothian	?	24	94		4,400
East-Lothian	?	60	180	13	6,000
Kilmarnock } Ayrshire }	?	3	40	30	
Fifeshire	?	?	?	21	
Dumfries coal region	45,000	10	55	6	
11. *Irish coal-fields.*					
Ulster	500,000	9	40?	6	
Connaught	200,000				
Leinster (Kilkenny)	150,000	8	23		
Munster (several)	1,000,000				

Tamworth; and the *Leicestershire* coal-field surrounds the town of Ashby-de-la-Zouch. The coal of the latter is far more extensively wrought than that of the Warwickshire field; but both being without iron furnaces, their produce is required only for the land sale, which extends southward through Buckinghamshire to the Thames. 8. The *Forest of Dean* is a remarkable detached coal-field in Gloucestershire, between the confluent rivers Wye and Severn, in which pits are wrought for the manufacture of excellent iron ores, and for the supply not only of the contiguous parts of Herefordshire and Gloucestershire, but also for a considerable land sale eastward towards Oxford. South Gloucestershire is in great

part occupied by a coal-field, which extends northward from Bristol, and supplies that city and the contiguous country with fuel. There are also valuable mines in *North Somersetshire*, the principal being those to the south-west of Bath, which supply the contiguous country, and have also an extensive sale eastward in Wiltshire and Berkshire. 9. The most extensive coal-basin of the west is that of *South Wales*, which, commencing in Monmouthshire, occupies a considerable portion of the counties of Glamorgan, Carmarthen, and Pembroke. The internal consumption of its coal in the manufacture of its native ores of iron, and of those of copper and tin brought from Cornwall and other parts, is enormous, and, besides supplying with fuel the whole of South Wales and its borders, Cornwall, and a considerable part of Somersetshire, it exports large quantities of stone-coal even to London. 10. The coal districts of the *East of Scotland* encircle the Frith of Forth in tracts of very irregular form, occupying large portions of the counties of East Lothian, Mid-Lothian, and West Lothian, of Stirlingshire, and part of Dumbartonshire, of Clackmannanshire, and Perthshire, and of Fifeshire, in the districts of Dunfermline, Kirkadly, Cupar, and St. Andrews. The coal of the whole of those districts is extensively wrought, chiefly for land sale to Edinburgh and the surrounding counties, and partly for shipment coastwise and for the celebrated iron-works of the Carron Company in Stirlingshire.

Lanarkshire, Ayrshire and Renfrewshire comprise nearly the whole of the irregularly scattered coal-fields of the *West of Scotland*, and their mines have been chiefly wrought, like those of Lancashire, for the supply of the great manufacturing population, of which Glasgow is the centre. The district of Airdrie, to the east and south-east of Glasgow, is also rising into importance in the manufacture of iron, from the excellent ores there found, so that the working of its coal has greatly increased.

There are also in Great Britain other very small coal tracts not sufficiently important to call for special notice.

11. The coal-fields of Ireland are comparatively unimportant. The principal are those of Castlecomer in Kilkenny, and the Queen's County, where pits are worked; pits are also worked near Killenaule, in the county of Tipperary; Dromagh and Dysart, in the county of Cork; Drumglass and Coal Island, in the county of Tyrone, which, with the Arigua coal-pits at the northern extremity of Roscommon, supplying some contiguous iron-works, complete the list of the Irish coal-mines in actual operation.

In addition to the enormous demands made on our national stock of coal by our own domestic consumption and our various manufactures, there is also a very large export trade in coal, which has greatly increased since the repeal of the duty, in 1845. In 1849, coal was exported of the declared value of 1,088,148*l*. This is doubtless an advantage for ships that might otherwise have had to go out in ballast, for they can now take with them a profitable cargo. Whether this lavish expenditure of our national wealth is reprehensible or not, is a question that has been very much discussed of late years, and has even been made the subject of parliamentary inquiry. The general opinion is that our stores of coal are all but inexhaustible. This opinion, however, as Mr. Sopwith justly remarks, "rests wholly on assumed data, and not upon accurate and detailed statistical accounts, such as alone could warrant a confident opinion. This question will ere long become a subject of serious concern, unless some measures are taken to found our calculations on a solid basis. It is an easy matter to assume that a considerable thickness of available coal extends over hundreds of square miles; but the different opinions formed by men of the highest respectability and talent, strongly prove how meagre and unsatisfactory are the only data on which their estimates are founded. It is not, however, the mere quantity of coal that is to be considered. Especial regard must be had to its quality, depth, thickness, extent, and position. Many of the inferior seams can only be worked in conjunction with those which, by their superior quality, repay the expense of working them at depths varying from 300 to 600 yards; and it may readily be conceived that inferior coal only could not be profitably raised from pits equal in depth to three or four times the height of St. Paul's Cathedral, unless the price of such inferior coal were raised to more than the present price of the best coal. . . . It is not the exhaustion of mines, but the period at which they can be profitably worked, that merits earnest and immediate attention."

The Table on the next page, from the valuable report of Sir H. De la Beche and Dr. L. Playfair (Mem. Geol. Survey, vol. ii.), contains the elementary analyses and economic value of British coals.

In proceeding to notice the methods of obtaining the coal, and the general economy of a mine, we will first refer to the collieries of Northumberland and Durham, as exhibiting the most perfect arrangements that have yet been made in this department of mining.

The first operation in coal mining is the sinking of a shaft, the site for which is generally determined by the previous operation of boring. The shaft is vertical, and is made to pass through the various strata containing the coal, and through as many of the beds of coal as may be worth working. The shaft is either cylindrical or elliptical in form, and from 10 to 15 feet in diameter. To prevent the loose strata from falling or being washed in, the upper portion of the shaft is bricked or walled, and where the ground is weak, this casing is continued down to the solid rock. It seldom happens that any great depth can be reached without liberating springs of water, which sometimes pour into the workings in such cataracts, that to continue the excavation seems perfectly hopeless. The water is, however, gradually excluded from the shaft by a skilful system of casing or *tubbing;* which consists in lining the shaft with three-inch boards, fastened to a circular wooden framework called a *crib*, attached to the side at certain distances. Metal cribbing is

now generally preferred, and some recent shafts have been completely lined with a strong casing of cast-iron to the depth of 40 fathoms (240 feet). The work, however, could scarcely be proceeded with for a single hour but for the assistance of the steam-engine, which is made to work night and day in drawing the water from the shaft. The sinking of the shaft is continued until the first workable seam of coal is reached, and the depth in the northern coal-field is rarely less than 25 fathoms (150 feet), and is usually much more, some shafts being 300 fathoms (1,800 feet); and an expense of upwards of 50,000*l.* has often been incurred before the seam intended to be worked is reached.

		Specific gravity.	Carbon.	Hydrogen	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke per cent.	Evaporative power	
Welsh Coals.	1	1.375	91.44	3.46	0.21	0.79	2.58	1.52	92.9	9.46	Anthracite.
	2	1.275	89.78	5.15	2.16	1.02	0.39	1.50	77.5	10.21	Ebbw Vale.
	3	1.304	88.66	4.63	1.43	0.33	1.03	3.96	88.10	9.94	Binea Coal.
	4	1.326	88.26	4.66	1.45	1.77	0.60	3.26	84.3	10.14	Duffryn.
	5	1.358	85.52	3.72	a trace	0.12	4.55	6.09	85.0	6.36	Pentrefelin.
	6	1.30	84.87	3.84	0.41	0.45	7.19	3.24	85.5	9.35	Graigola.
	7	1.32	80.70	5.66	1.35	2.39	4.38	5.52	64.8	7.47	Ponty Pool.
	8	1.34	75.15	4.93	1.07	2.85	5.04	10.96	62.5	8.84	¾ Rock Vein.
	9	1.29	73.84	5.14	1.47	2.34	8.29	8.92	56.0	8.0	Coleshill.
Scotch	10	1.277	74.55	5.14	0.10	0.33	15.51	4.37	49.8	7.08	Dalkeith, Jewel Seam.
	11	1.316	76.94	5.20	a trace	0.38	4.37	3.10	53.5	7.71	Do. Coronation Seam.
	12	1.20	76.09	5.22	1.41	1.53	5.05	10.70	58.45	8.46	Wallsend, Elgin.
	13	1.25	79.58	5.50	1.13	1.46	8.33	4.00	52.03	7.56	Fordel Splint.
	14	1.29	79.85	5.28	1.35	1.42	8.58	3.52	56.6	7.40	Grangemouth.
English	15	1.25	81.70	6.17	1.84	2.85	4.37	3.07	59.2	7.3	Broomhill.
	16	1.283	73.52	5.69	2.04	2.27	6.48	10.00	57.8	8.52	Parkend, Sydney, Forest of Dean.
Irish	17	1.59	80.03	2.30	0.23	6.76	in ash	10.80	90.1	9.85	Slievardagh.

When, however, this desirable object has been attained, the sinking of the shaft is discontinued, and a broad straight passage, called a *bord* or *mother-gate*,[1] is driven from it into the seam of coal in opposite directions. This bord is 12 or 14 feet broad, and of the whole height of the seam, so as to expose the rock above, which is now called the *roof*, and also the stratum below, which forms the *thill* or floor. It is also necessary to drive a passage, called the *drip-head*, *dip-head*, or *main level*, for collecting the water of the mine. This passage is not usually straight, but the object is to preserve throughout its length a constant level, so that the water may collect like a gutter along one side of its floor. This gallery forms the limit of the colliery in the direction of the dip, for it bounds the area drained or *won* by that shaft. From this level gallery numerous other galleries are driven towards the rise of the strata, till they reach either the outcrop of the seam, or the dip-head gallery of an adjoining colliery, which is called the *rise* colliery. The direction of the bords is arranged so as to follow the natural cleavage of the coal, which forms their sides, and, consequently, is not always at right angles with the dip-head. When a bord has been excavated some distance, narrow passages, called *headways*, are driven from it, at regular intervals, on both sides, and exactly at right angles, if the natural cleavage of the coal be cubical, as it generally is; and when these have been driven 8 or 10 yards, they are made to communicate with other bords, which are opened parallel to the first, and on each side of it. In this way, the bed of coal is entirely laid open, and intersected by broad parallel passages, about 8 yards apart, communicating with each other by narrower passages or headways, which cross them at right angles, and also traverse the whole extent of the mine, breaking up the seam into immense squares or rectangular pillars, which are left standing between the two. In this state, a coal mine has been aptly compared to a regularly built town, the bords being the principal streets, the headways the narrower streets which cross them, while the pillars of coal form the masses or blocks of buildings. When the two cleavage planes of the coal are not at right angles, all the blocks are rhomboidal, and much labour is saved by following the natural cleavages, which are usually parallel throughout a vast extent of country, and are even independent of the curvatures of the strata.

As the pillars of coal which are left to support the roof form frequently as much as three-fourths, and never less than one-third of the whole seam, many methods have been contrived for removing them without danger. The best method of working is that called *panel-work*, by which the mine is divided into districts or panels, separated from each other by walls of coal forty or fifty yards thick. The coal is extracted from each in succession, beginning usually with the one most distant from the shaft. Large pillars of coal are first left between the bords to support the roof; the pillars themselves are then removed, the roof being supported in the mean time by wooden props, and the place where these props occupy the situation of a pillar is called a *jud*. In time, the jud is removed, and then the unsupported roof of the mine falls in. The heap of ruins thus occasioned by the successive drawing of contiguous juds, is called a *goaf*. Corresponding with this heap of rocky frag-

(1) That is, a "principal road," the Saxon meaning of *gate* being *road* or *way*.

ments, and produced by it, is a cavity in the mine, like an inverted basin, including a thin belt of air, which surrounds and partly permeates the goaf. This has been the source of dangerous accidents, as will be noticed hereafter.

Fig. 573, is the plan of one story of such a mine, in which the panels, *a a a a*, are not entirely laid open by galleries; *b b* are laid open, but no pillars as yet removed; in *c c*, the pillars are being extracted and

Fig 573.

the roof is falling in, its ruins forming a *goaf;* the panel *d*, is entirely worked out and abandoned.

When the prospects of the mine appear to be favourable, another shaft is, in some cases, sunk at a short distance (perhaps from 12 to 20 yards) from the first, and when a communication has been established between them, one is made the *downcast* and the other *upcast;* that is, the air necessary for the ventilation of the mine is made to descend the downcast shaft, and a corresponding stream of air to ascend the upcast shaft. The air is set in motion by means of a large fire, kept constantly burning in some part of the upcast shaft. A portion of the air in contact with the fire in this shaft undergoes the ordinary chemical change which takes place in atmospheric air in the process of combustion, and is decomposed: the nitrogen is separated, and the oxygen, uniting with the carbon of the fuel, forms carbonic acid gas. Both these gases, as well as the portion of atmospheric air which remains undecomposed, being heated, are expanded, and occupy a proportionally larger space than the same weight of common atmospheric air, and are hence borne upwards in a strong ascending current. Now if a free communication be established between the two shafts, an equal current must at the same time descend the second or downcast shaft to fill up the partial vacuum which has been made in the first. In this way a power is generated capable of forcing a current of fresh air far beyond the distance to which any mine extends. The great generator of this power is the fire, and this power will act with a force and steadiness proportionate to the degree of heat steadily maintained at the bottom of the upcast shaft.

When two shafts have been sunk, and a horizontal road or communication is made between them, the next operation is to carry forward a mainway from the foot of each shaft, and then to make a road from the extremity of one mainway to the extremity of the other. If a door be now placed in the road which leads directly from the foot of the one shaft to the foot of the other, the air cannot then pass that way, but must go round along the one mainway across to the other, and thus to the foot of the shaft in which there is the fire, up which shaft the current must ascend. To whatever distance we suppose the mainways, the sideways, and all the other works of the mine to be carried, communications may thus be made between them, and by means of doors properly placed the circulation of the air may be conducted and guided through them to any extent, and in any direction that may be desired. Fig. 574, will show the principle of

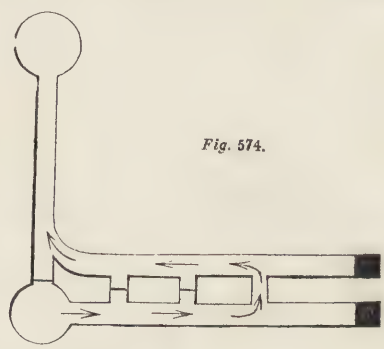


Fig. 574.

these ventilating arrangements. The arrows indicate the course of the air through the underground passages, from the downcast to the upcast shaft; and the lines drawn from one pillar to another show the trap-doors, or partitions, which prevent the current of air diverging to the upcast shaft before it has swept the more distant workings.

The supplies of fresh air passing into a mine must, of course, vary considerably. In the Wallsend colliery they vary from 2,000 to 3,000, and occasionally 3,800 cubic feet per minute. In some of the large workings, the air has to traverse many miles of gallery before it reaches the upcast shaft, and is frequently twelve hours in doing so, moving at the ordinary rate of 2 or 2½ feet per second. Many coal mines are worked without this second shaft, its place being supplied by dividing the single shaft into two distinct portions, by means of an air-tight partition, called a *brattice*, one division being downcast, and the other upcast. The larger shafts (those 15 feet in diameter) are sometimes divided into three parts, one of which is used for raising the coal to the surface, another for working the pumps for the drainage of the mine, and a third for ventilation, for bringing up the air that has passed through the workings.

The arrangements thus far explained for sinking a shaft and driving galleries into one seam of coal being conducted with success, the sinking of the shaft is continued to a second or third seam. Small underground pits, called *staples*, are sunk at intervals from the workings on the upper seam to those on the seam below, for the purpose of promoting ventilation. In

this way an extensive colliery is formed; but the regularity and uniformity of the workings are liable to be greatly disturbed by faults and local accidents. For example, if the roof be of hard sandstone and the floor of soft clay, the downward pressure will tend to force up and displace the floor; this is called a *creep*. If, on the contrary, the roof be soft, it will sink in and form what is called a *crush;* and if both roof and floor are moderately hard and tough they will gradually meet midway. The gradual progress of a creep is shown in Fig. 575, by which the passages become

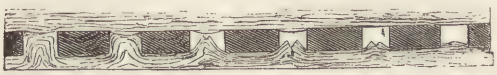


Fig. 575.

choked up, and the pillars of coal are cracked and rendered useless. By the method of working in panels, however, a creep in one panel is prevented, by the thick surrounding walls, from spreading into the adjoining panels.

The coal is excavated by a set of men named *hewers*. They commence by cutting a narrow fissure in the lower portion of the coal, next the thill or floor; they then define the size of the mass intended to be brought away, by cutting deep vertical grooves on each side of the bottom fissure: the mass is then broken down by driving in wedges, or by the force of gunpowder, the latter method being usually adopted in the deep northern mines. A hole about a yard deep is drilled near the roof, and the cartridges of gunpowder, called *shot*, are inserted. Sometimes two or three shot are inserted; the holes are filled up with coal-dust, and the fuse is fired. By this means from 60 to 80 or 100 tons of coal may be brought down at once. The coal is put into baskets, called *corves*, and drawn along the tram-road by lads called *putters* as far as the principal galleries, or headways, where it is received into wagons, called *rolleys*, several of which, being fastened together, are drawn by a horse to the bottom of the shaft, and thence raised by means of the steam-engine to the surface. The small pulverized coal is separated from the larger by being passed over gratings or screens, usually composed of bars of iron half an inch apart, mounted in a frame-work with a convenient slope, so as to allow the coals to slide down easily into the wagons below. The small coal which passes through the screen is either delivered in wagons for immediate sale, or is collected into heaps, or is hoisted up and passed through screens in which the bars are set closer together, and is thus sorted into *rough*, *small*, and *dust*. The small coal, which was formerly burnt to waste at the mouth of the pit at the rate of about a million tons per annum, is now profitably employed in making coke for locomotive engines, iron works, brewers, &c., and for consumption abroad. It is also a curious sign of the times that in some collieries machinery has been erected for crushing large coal into small, in order to meet the increasing demand for coke.

"Pit-coal is produced by a severity of labour, and risk of personal safety to the miner, which the workman of no other occupation is exposed to. The pitman descends 200, 300, and sometimes more than 500 yards into the bowels of the earth, and there traverses subterranean passages, frequently of two or three miles in extent, to his work; where, by the glimmering of a small candle, or more imperfect lamp, in a space seldom six feet high, and oftener three or four, he labours in a stooping posture, sometimes lying on his side for eight or ten hours together, in an impure atmosphere, to extract the mineral, which above ground is diffusing light, heat, riches, and enjoyment. In such a situation often, without a moment's warning, he is overtaken by destruction. The gases generated in such abundance in the mine, from some accident suddenly explode and fill the pit with death. In an instant, and in the most fearful manner, he is scorched and shrivelled to a blackened mass, or is literally shattered to pieces against the rugged sides of the mine; or, if out of the range of this terrible piece of ordnance, in a few seconds the *after-damp* spreads itself in every direction, and poisons beyond recovery all that it may reach. Humanity has too frequently to deplore these fearful accidents."[1]

The accidents arising from the falling in of the roof, and the bursting in of water, are not peculiar to coal mines. The great and terrible source of danger which distinguishes coal-mines, and especially those of the great northern coal-field, is the escape of large quantities of *fire-damp*, or carburetted hydrogen gas, which, mingling with the air of the mine in certain proportions, forms a mixture which explodes on contact with flame. This gas is very much lighter than common air, mingles readily with it, and when poured out into the workings, moves along with the ventilating current in the direction of the upcast shaft. The quantity of gas thus poured out is very considerable, but subject to great variation, some seams being more *fiery*, or full of gas, than others; and, in working these fiery seams, it is not uncommon for a jet of inflammable gas to issue from every hole made for the gunpowder used in blasting. But, in addition to this constant supply, there is danger of sudden discharges from cavities in the coal, laid open by the hewer's pick-axe. The gas issues from these cavities with considerable noise, and forms what is termed a *blower*. These blowers are sometimes so constant in their action, that the gas is collected and conveyed by a tube into the upcast shaft, continuing for months or years to pour out hundreds or thousands of hogsheads of fire-damp per minute. When thus provided for, the blowers are not, necessarily, a source of danger; but when one of the reservoirs containing the pent-up gas of centuries, and consequently under an enormous pressure, is suddenly broken open, the gas is set free in torrents, and, mingling with the air of the mine, forms an explosive mixture which the first spark or naked flame may ignite, and thus cause a fearful destruction both of life and property. Nor is the explosion itself always the thing to be dreaded most; for the ignition of the fire-damp kindles the coal-dust, which always exists in great quantities in

(1) Report of the South Shields Committee.

the passages, and, in a moment, causes the mine to glow like a furnace. This conflagration is necessarily succeeded by vast volumes of carbonic acid, or *choke-damp*, as it is emphatically called, from its suffocating character, and this destroys those whom the explosion had spared.

It was to guard against the explosion of fire-damp, that Sir Humphry Davy invented his safety lamp, Fig. 576, a beautiful and simple contrivance, consisting merely of a common oil lamp, the flame of which is completely enclosed within a cylinder of wire gauze, which, as already explained in our article Candle, will not admit of the passage of flame; so that although the lamp be introduced into an explosive mixture, the flame will not pass through the gauze to ignite it. Of course, the efficacy of the lamp depends on the soundness of the wire gauze, for if this be broken and injured, the flame is not protected; or if the lamp be moved swiftly through an explosive atmosphere, the flame may be blown against, and even through the meshes of the gauze, and, in either case, might lead to an explosion. When the lamp burns in an atmosphere highly charged with fire-damp, the gas gets within the meshes, and burns with a blue flame, which heats the wire gauze to redness. Even this state of the lamp will not produce an explosion, but of course it was never intended that the workman should go on working with the lamp in this state. The blue flame within the lamp ought always to be a caution to him to retire, until the mine be rendered safe by ventilation. The Davy lamp has been in some respects improved upon by Dr. Clanny, whose safety lamp, Fig. 577, differs but little in form from the Davy. The gauze is of the fineness of 1,296 meshes to the square inch. The air for supporting combustion passes through the meshes down upon the flame, which is surrounded by a thick well-annealed glass cylinder. By this means, the atmospheric air when mixed with fire-damp at the exploding point, becomes greatly expanded in volume, and passes off in safety. It gives a better light than the Davy, and burns for a longer time. When the flame is extinguished by fire-damp, the blue flame in the whole cylinder disappears quietly, thus indicating to the miner the nature and extent of fire-damp contained at the moment in the atmosphere of the mine. The flame of the lamp being surrounded by a glass cylinder, prevents any blown or unmixed fire-damp, or strong currents of fire-damp, however explosive or dangerous, from coming in direct contact with the flame, nor can the pitman unscrew it for the purpose of lighting his pipe. From too great reliance, in all cases, on the safety lamp, from neglect, and from various other causes, this lamp has disappointed the expectations of those most interested in its use, and experienced men now look for safety rather to improved methods of ventilation than to contrivances for lighting the mines. The general plan of ventilation now in common use will be understood from the following details.

Fig. 576.

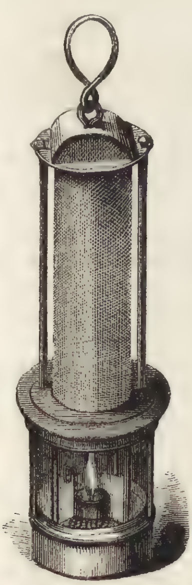


Fig. 577.

When a seam is begun to be worked, there is, of course, only one available shaft for ventilation, and this is divided into two portions, as at *a b*, Fig. 578, for the ascending and descending currents: and as it is not safe for the men to be ever more than a few yards in advance of the course of the current, they begin working the seam with two parallel bords, connected at intervals by cross passages, which are successively stopped by wooden partitions, *c c c*, leaving no communication except through the one last opened, or that which is furthest from the shaft. Temporary partitions are also placed at *d d*, to direct the current to the very spots where the men are at work, as at w w. When the workings are more advanced, the direction of the current through every part, by *stoppings* or partitions, becomes a matter of no small complexity, as will be seen by the plan Fig. 579, where the arrows represent the course of the air from the downcast shaft, *a*, through all the galleries to the upcast shaft, *b*. It will be seen, that in most places the current is divided between the parallel bords; this is called *double coursing*, and its advantage is, that if any part of the mine is more fiery or dangerous than the rest, the current can there be confined to one course, and thus have its

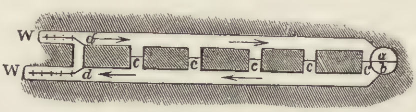


Fig. 578.

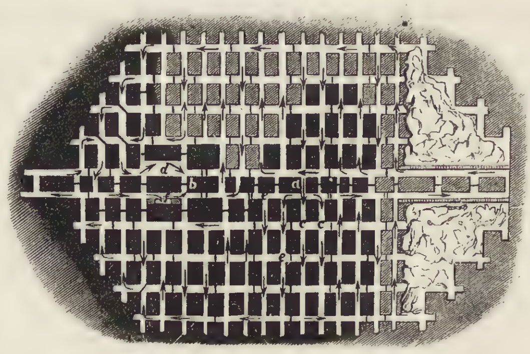


Fig. 579. Plan of a Coal-Mine.

velocity doubled; while in the parts containing least gas, the same current can be allowed to expand into three passages, which is called *treble coursing*. The double stoppings in Fig. 579, represent those in which doors of communication are required. These are made in pairs, in order that a person may pass through them, as a barge through a canal lock, without allowing the main bodies of air to communicate. To ensure this, they are sometimes made even treble, and a boy is placed in charge of each pair or set of three, whose duty it is to prevent them from being all opened at once.

As it is not safe to allow the foul air from the more fiery parts of the mine to come in contact with the fire at the bottom of the upcast shaft, which sets the whole ventilating current in motion, it is usual to divide the air, as it enters the mine by the shaft *a*, into two distinct currents, one of which proceeds through the passages *e e* into the safe parts of the mine only, while the other, *c c*, circulates through the fiery parts represented by the lighter shade, including the goafs, or old abandoned workings, which are always the most dangerous receptacles of gas. The purer current alone is allowed to pass through the furnace *f* before entering the upcast shaft *b*. The other current is conducted through *d*, and enters the shaft at a higher level by a tunnel cut obliquely through the roof of the seam, as in Fig. 580, where S represents the upcast shaft, B the impure current, and A the purer current, feeding the furnace, which, when thus constructed, is termed a *dumb* furnace.

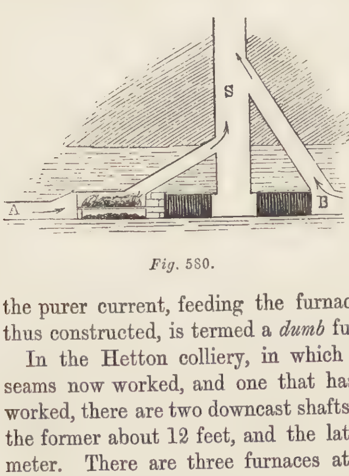


Fig. 580.

In the Hetton colliery, in which there are two seams now worked, and one that has formerly been worked, there are two downcast shafts and one upcast, the former about 12 feet, and the latter 14 feet diameter. There are three furnaces at the bottom of the upcast, each about 9 feet wide and about 4 feet length of grate-bars. The depth of the upcast and one downcast is 150 fathoms; and of the other downcast 176 fathoms. The quantity of air introduced into the mine by the action of these furnaces was 168,850 cubic feet per minute, at a cost of about eight tons of coal per day. The rate of motion of the air was 1,097 feet per minute. This whole current is divided by splitting into sixteen currents, of above 11,000 cubic feet per minute, having on an average a course of $4\frac{1}{4}$ miles each. This distance is, however, irregular; the greatest length of course being $9\frac{1}{10}$th miles. The effective velocity of the current in the actual workings of the mine is much checked by the multiplication of passages, friction, and other causes, and is thus reduced to from 3 to 5 feet per second; the smaller quantity being about the maximum rate attainable by the natural current in a small mine, where there will generally be from 1 to 3 feet. It is estimated that the minimum quantity of fresh air required for the support of life in a mine is about 15 or 18 cubic feet per minute for each man employed.[1]

The goafs, or abandoned workings, are sometimes of vast extent, and are known to occupy from thirteen to ninety-seven acres of ground. They may be compared to enormous inverted bowls or basins, in which the inflammable gas from various parts of the mine accumulates, and from its lightness occupies, at first, the upper part of the goaf: as it increases in quantity, or even as the atmospheric pressure diminishes, it may suddenly fill the goaf and issue from its lowest edge as from the edge of an inverted bowl, and, mingling with the air of the mine, form an explosive mixture, thus giving rise to many sad accidents. Such appears to have been the origin of the explosion in Haswell colliery, Durham, in September 1844, by which ninety-five persons perished. Dr. Faraday, who, in conjunction with Sir Charles Lyell, visited the mine after the accident, with a view to devise some remedy against the recurrence of similar accidents, recommended that the goaf itself be ventilated. He thought it would not be desirable to attempt this by driving the contents of the goaf through any parts of the mine which are occupied by human beings; but that the goaf cavity might be exhausted of noxious air by means of a pipe, rising as high as possible, from four to eight or ten feet into it, and communicating at its other extremity with the upcast shaft.

Some interesting remarks respecting this explosion, and on the ventilation of coal-mines, were made by Dr. Faraday, at the Geological Section of the British Association, in 1845. Dr. Faraday remarked, that the more he pursued the inquiry into the means of preventing such accidents, the more he was disheartened at the apparent hopelessness of finding out any good general remedy. The explosions were not simply the effects arising from the mixture of gases, but from the combustion of the coal-dust and coal-gas which the first explosion made. In the fatal case at Haswell, the place where the accident originated had been ascertained, and the progress of the fire could be traced on the scorched beams and props of the galleries, and by the deposits of coke made from the coal-dust which the explosion raised. To this circumstance the great force of the explosion was due, and not to the first escape of gas. A similar explosion had been known to take place in a cotton-wadding manufactory, the whole atmosphere of the place being fired by means of the particles of cotton in it. Of all the workmen killed in the Haswell accident, perhaps not one was really burnt to death, but suffocated by the choke-damp. In one part of the workings, the explosion had produced sharp vibrations, like the firing of gunpowder; and in another, the burning went on slowly, like a common fire. But, although two panels were blown into one, and solid stoppings of brickwork thrown down, there was no indication

(1) Mr. N. Wood's Evidence—Report of Lords' Committee on Accidents in Coal-mines. 1849.

of accident in the shaft. If the stoppings had not been blown down, and the supply of air had continued, the mine would have taken fire, and the men been burnt instead of choked. Since the late investigation, many hundred plans had been submitted, urging ill-considered and contradictory measures. Every part of the Haswell Colliery had been examined, accompanied by the mine-viewer, and recommendations had been received from the best informed men on the spot; and they were convinced that the conditions under which such accidents happen were so variable, that no general practical rule could be obtained. Far more information, however, was required. The plan of splitting the air courses was good, as far as the power of the upcast shaft admitted; but if carried too far, it would produce stagnant points, which could not be prevented by any arrangement consistently with the ever-moving condition of the works. The abolition of the use of gunpowder and lighted candles would, in some cases, double the price of coals. But the great source of danger was the mental condition of the miners. With regard to the present race this was so hopeless that nothing could be done for them. Although smoking was strictly forbidden, they had been known to contrive to light their pipes in dangerous workings even from the Davy lamp; and Dr. Faraday had himself, on one occasion, sat down with an open candle to watch the preparations for blasting, and when he inquired for the gunpowder, was told he was sitting on it. Dr. Faraday expressed his opinion of the safety of the Davy lamp when properly used, and of its being a complete and practical contrivance, to which he would willingly trust his own life, as he had already done on many occasions.[1]

Various other contrivances have been made for promoting the ventilation of the northern coal-mines. In some cases, towers or chimneys have been built over the upcast and downcast shafts, with large cowls turned by vanes, as in Fig. 581, so that one may always present its mouth and the other its back to the wind. Mr. Brunton proposes to ventilate collieries by a modification of the fan, for which purpose immediately over the upcast shaft is constructed a hollow drum with radial compartments, through which the air is discharged with a degree of force due to the velocity with which the drum revolves. The drum, shown in section, Fig. 582, is 22 feet in diameter, with radial compartments, R C, each 6 feet long, and revolving 180 times per minute. "Taking 16 feet as the mean diameter of the compartments, the centrifugal force at 180 revolutions will be 88.5, which, multiplied by the weight of 6 cubic feet of air ($=\frac{444}{1000}$ths of a pound), will give a pressure of 39lbs. on the square foot as the amount of rarefaction produced, which is much beyond what is obtained by the furnace. If driven to 210 revolutions per minute, it would produce a rarefaction of upwards of 50lbs. on the square foot; or, unconnected with any lengthened air-course (*i. e.* mere displacement), it would discharge more than 800,000 feet in a minute." This fan is very simple in construction; it moves in a well-oiled foot-pivot, and when at rest offers no resistance to air ascending from the pit. By connecting such an apparatus with a 12-horse steam-engine, the ventilation of the mine may be suddenly and powerfully increased; but for common use one-third of that power may be sufficient. In a trial made with this apparatus at Gelly Gaer Colliery, the rarefaction maintained in the upcast shaft was equal to $2\frac{1}{2}$ inches of water, or 13lbs. on the square foot: this, of course, produced a strong current through the workings of the colliery, one of the air-ways of which, 20 yards long, has a mean area of only $9\frac{1}{2}$ superficial feet; yet such was the power of the machine that 18,000 cubic feet per minute were propelled through this passage at a velocity of 32 feet per second, and afterwards, in its way to the upcast pit, through an opening of only 4 superficial feet area, at a velocity of 70 feet per second. By stopping the air in the downcast shaft, and setting the fan in motion, the whole of the colliery was subjected to a rarefaction equal to a sudden fall of the barometer of about two-tenths of an inch. This diminished pressure could be carried to a much greater extent, so as to draw off the fire-damp from the goaves and fissures, during the absence of the workmen and their lights.

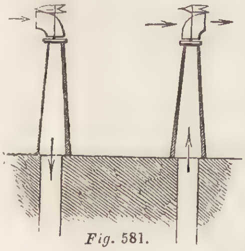


Fig. 581.

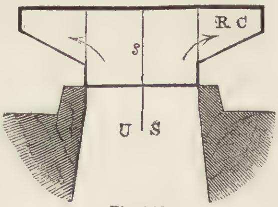


Fig. 582.

The direct agency of steam has also been successfully employed by Mr. Goldsworthy Gurney in the ventilation of a mine. Instead of a fire at the bottom of the upcast shaft, a high-pressure steam-boiler is constructed, from which the steam issues in jets, heats the column of air in the shaft, and expels the whole column with great force, whereby a rush of air to supply its place is immediately made from the galleries of the mine. The high-pressure jets thus act as a force-pump in front, producing compression, and as a draw-pump behind, producing exhaustion. In fact, the power of producing exhaustion is quite remarkable, and promises to be of the greatest importance in the ventilation of coal-mines.

Next in importance in England to the Northern coal-field is the South Staffordshire coal-field. This is encircled on all sides by the new red sandstone formation; the coal-measures at the line of junction being usually broken suddenly off by faults, whereby the strata are brought up against the new red sandstone, the remaining portion of them being continued beneath it to an unknown extent. This is proved to

(1) For this part of our subject relating to the ventilation of coal-mines, we are chiefly indebted to Mr. Tomlinson's "Treatise on Warming and Ventilation," published in Weale's Rudimentary Series.

Fig. 583. SECTION ACROSS THE THICK COAL-FIELD, SOUTH STAFFORDSHIRE.

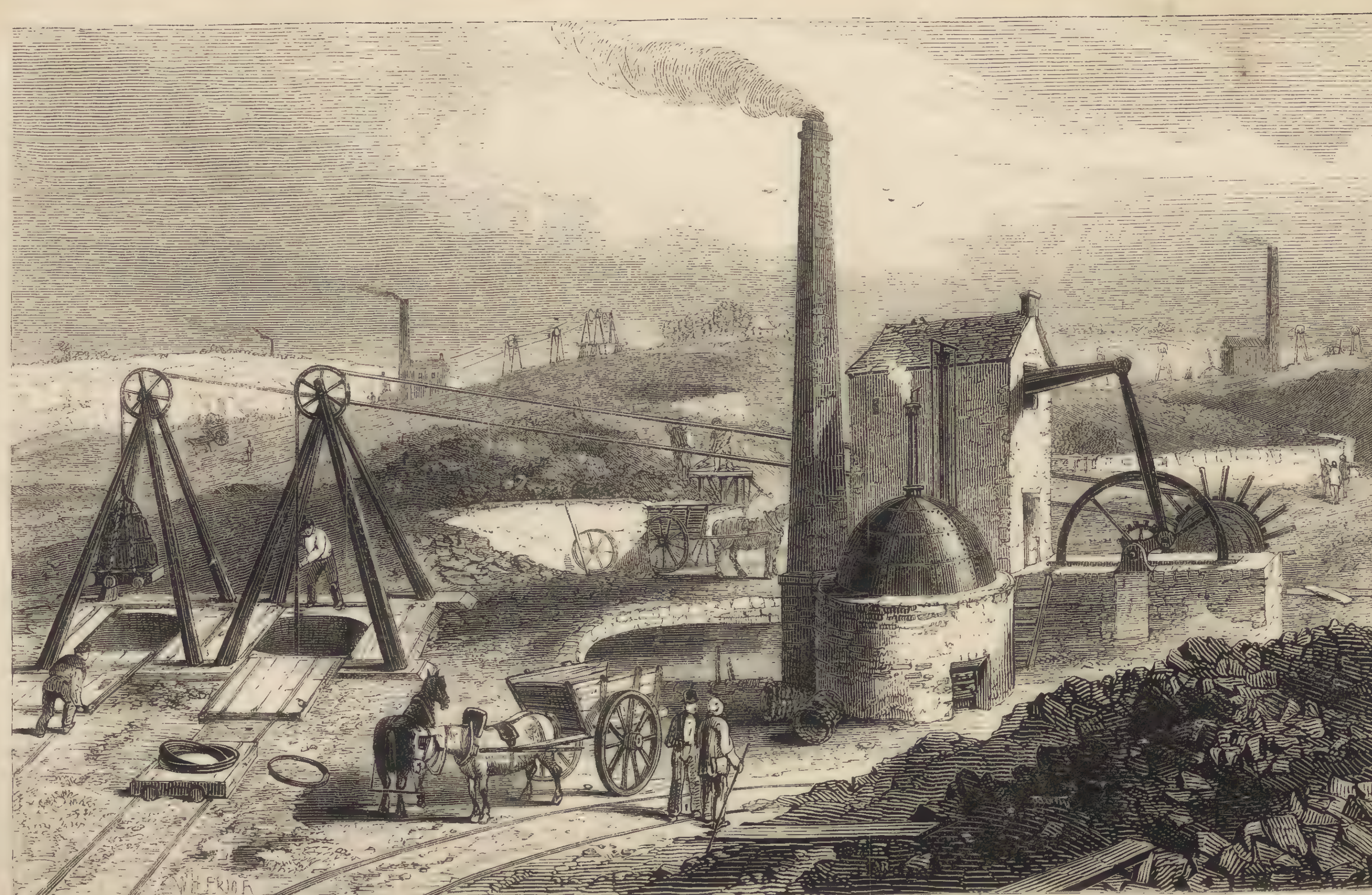
L Level of the sea.
s Summer House Hill.
S Sinking.
K King's Swinford: thick coal at 120 yards: further on at 190 yards, and at 95 yards at Barrow Hill fault. Strike NE. SW. Upcast 190 yards.

B Barrow Hill, 600 feet: coal charred and strata broken up by the trap *t*. On each side the coal is charred and altered by the intrusion of trap.
O The Old Park: probable fault; ground not proved.
D Suburbs of Dudley: lower coal and ironstone cropping out.
D C Dudley Castle: 528 feet; thin patch of coal.

D P Dudley Port Trough. *l* limestone.
F Boundary fault. Upper coal dislocated 80 yards.
W B Christ Church, West Bromwich: 324 feet above the sea level.
E Earl of Dartmouth's works. Ten-yard coal. *t* trap. *c* coal wedged out in smut.
S P Sandwell Park.

be the case at West Bromwich, and at King's Swinford, as shown at both the eastern and western limits of the field. (See section, Fig. 583.) This field forms an irregular oblong, bounded on the east by a line running from West Bromwich on the new red sandstone, by Walsall, on the Wenlock limestone, and continued westward of Lichfield to near Rugeley, where it comes to a point, the western boundary running thence nearly south by Cannock and Wolverhampton to Stourbridge; the southern limit being nearly coincident with the straight line drawn from Stourbridge to Hales Owen, and continued till it cuts the line of the eastern boundary, prolonged in a southerly direction. Its extreme length is 21 miles, and its general breadth from 6 to 7, thus forming a mere speck on the map; but from its enormous stores of mineral wealth, and the consequent density of its population, superior in importance to any other tract of equal extent in the kingdom.

"In traversing much of the country included within the above-mentioned boundary of red sandstone, the traveller appears never to get out of an interminable village, composed of cottages and very ordinary houses. In some directions he may travel for miles, and never be out of sight of numerous two-storied houses; so that the area covered by bricks and mortar must be immense. These houses, for the most part, are not arranged in continuous streets, but are interspersed with blazing furnaces, heaps of burning coal in process of coking, piles of ironstone calcining, forges, pit-banks, and engine-chimneys; the country being besides intersected with canals, crossing each other at various levels, and the small remaining patches of the surface-soil occupied with irregular fields of grass or corn, intermingled with heaps of the refuse of mines, or of slag from the blast-furnaces. Sometimes the road passes between mounds of refuse from the pits like a deep cutting on a railway; at others, it runs like a causeway, raised some feet above the fields on either side, which have subsided by the excavation of the minerals beneath. In one place, observing that the turnpike road sloped a good deal on one side, I asked the driver if it would not be repaired; to which he replied that they were still working the coal beneath it, and that they would probably wait to see if the road would not right itself by sinking on the opposite side, and so become level again. The geologist would find no country more instructive for the study of the subsidence of dry land. The whole country might be compared to a vast rabbit-warren. It is a matter of every-day occurrence for houses to fall down, or a row of buildings inhabited by numerous families to assume a very irregular outline, from what they call a *swag*, caused by the sinking of the ground into old workings. It is often a serious matter to find a sound site for a church or school-building. . . There is an instance in the parish of Sedgley of a church and parsonage-house, recently erected, composed of wooden framework, which will admit of their being screwed up into the perpendicular again whenever they may be thrown out of it. Cellars beneath dwelling-houses are occasionally filled with choke-damp, arising from old work-



COAL.—WHIMSEY OR ENGINE DRAWING COAL IN THE STAFFORDSHIRE COLLIERIES.

ings, to a degree that makes it dangerous to enter them. On one occasion, a gentleman remarked that

Fig. 584. TOTTERING HOUSE, SOUTH STAFFORDSHIRE COAL DISTRICT.

perhaps I was not aware that the steps by which I entered his house (in a town) were built on an arch covering the mouth of an old coal-pit. Early potatoes for the London market are raised in ground near Dudley, heated by steam and smoke, which proceed from an old colliery which has been on fire for many years, and which may be observed bursting through the crevices of the rock on the side of the road close to the town." [1]

The geological features of this formation have been developed by Sir R. I. Murchison, in his magnificent work, "The Silurian System," (4to, London, 1839,) in which he has developed a distinct series of geological formations which, being best exhibited in South Wales, the country of the ancient *Silures,* the term *Silurian System* has been applied to them. By means of these researches the important fact was determined that the Dudley limestone is an isolated protrusion of two Silurian limestones, and not a portion of the carboniferous, or mountain limestone, to which its position, rising immediately as it does from below the coal-measures, had caused it to be referred. "Notwithstanding that this field contains the thickest seams of coal in England, its associated strata are of very small dimensions compared with the equivalent series in other parts of the kingdom. The millstone grit is scarcely represented; and the mountain limestone, the usual base of the system, as well as the old red sandstone, are entirely absent. The absence of these formations and the immediate contiguity of the coal-measures, and the Dudley or Wenlock limestone, one of the Silurian rocks, constitute a remarkable and important character of this coal-field. These ancient Silurian rocks, however, the real substrata of this coal-field, instead of appearing in the regular order of their superposition, rise up irregularly like islands through the coal measures near Dudley and Sedgley, and form the eastern boundary of the field near Walsall." (See the general section across the field, Fig. 583.)

The Silurian system forms a complete succession of fossiliferous strata interpolated between the old red sandstone, and the oldest slaty rocks. It consists of four principal divisions, beginning with the more recent: 1, the Ludlow or Sedgely limestone; 2, the Wenlock or Dudley and Walsall limestone; 3, the Caradoc sandstone; and 4, the Llandilo flags. This Silurian is separated in the geological series of formation from the deposits of the carboniferous era by the vast series of the old red sandstone system; and thus the coal measures of England are usually included between the two great red-coloured systems of rocks, viz.—the old red sandstone, below; and the new red sandstone, above them. This last system begins immediately below the lias in a descending series, with 1, Saliferous marls; 2, Red sandstone and quartz on conglomerate; 3, Calcareous conglomerate expanded in Durham into the magnesian limestone; 4, Lower new red sandstone, which immediately overlies the coal measures. The great thickness of these lower sandstones was proved in the parish of West Bromwich by sinking through them to the coal. "These workings descend through a variety of red spotted sandstones, marls, and courses of calcareous grit and conglomerate. It was well known that the coal-seams of the adjacent Dudley coal-field do not deteriorate or thin out near these works, but are simply lost by faults. The existence of the upper beds of coal having been previously ascertained by borings carried down to a depth of more than 700 feet below the surface, they and the lower beds have since been reached by sinkings, and are now in full work. . . . The success of the attempt was derided by many of the miners of the adjacent coal-field, it having been till very recently the prevalent belief that this red sandstone entirely cut off the coal, and that the latter would never be found under the former; but this notion is fast vanishing, and will soon be entirely removed.

"Owing to the great disturbances to which that part of the field which contains the ten-yard coal has been subjected, whether by the upheaving of the trap and Silurian rocks, or by great dislocations, the same measures are reached at very various levels in different localities. Thus in some situations shafts are sunk through shale and clunch with bands of sandstone to depths exceeding 100 yards before traces of coal are met with; while in many collieries, as near Wednesbury, all the overlying seams of coal and coal-smut which connect the coal measures with the lower new red sandstone have been removed, or have thinned out, and the ten-yard coal rises at once to the surface. It was this natural out-crop of the thick coal which led our ancestors to work it in open quarries. It has been stated that the lower coal and iron-stone measures crop out from under the ten-yard coal, and extend into the great Wolverhampton field. In their spread to the north, however, these strata assume very different characters from those which they possess

(1) Report of the Commissioners, &c.

when they underlie the thick coal in the portion of the field south of Bilston and Wednesbury. In most of the works which have hitherto been established in the region of the ten-yard coal, three courses only of workable iron ore have been ascertained; whilst in the Wolverhampton district six valuable bands are wrought. By a band is meant one of those groups of concretions in which two or more courses of iron ore are often separated from each other by shale or clunch."

The operations of getting out the ten-yard coal, which is peculiar to South Staffordshire, will be understood from the following description, and by referring to the large engraving.

The first class of labourers are the *holers*, seen at work in the centre of the picture. These men undermine, or make a hole, under the mass of coal, by cutting out with light picks the bottom measures, building up small supports called *cogs* of stone to support the mass of coal under which they are at work. A sufficient extent of coal having been thus undermined, they next cut upwards a cavity between the mass of coal which is intended to fall and that which is intended to stand, as a pillar to support the roof of the mine. This cutting, or separating the coal from the pillars, must be performed on both sides of the mass which is to be let fall, and also at the end where it joins on to the remaining solid mass. The mass is not, however, completely separated from the pillars, but small supports, called *spurns*, are still left, which connect the mass to be thrown down with the pillars. The coal is cut through until the parting is reached which forms a natural division of the lower measure from the next above it; or sometimes two measures are cut through at once, but always to a natural parting, the cutting being made perpendicularly up the face of the pillar, but any shape, so as just to admit the pick and the arms of the workmen on the side of the coal to be thrown down, so that a vertical section of the cutting would present the appearance shown in Fig. 585. After the cutting is completed

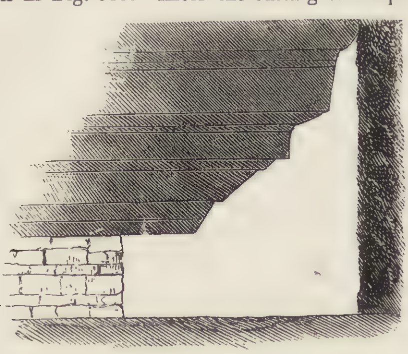


Fig. 585.

and the men have withdrawn, the most skilful, armed with a long pricker, cuts and tears away the spurns and the cogs, when the mass of several tons falls together. In this way, after holing out the under part of the coal, all the rest of the measures are brought down successively by cutting.

The men engaged in this work are paid by the *stent* or *stint*, a certain number of feet of work; which, however, varies in different mines: it was stated by one workman to be 2 yards in, 3 feet wide, and 2 feet 3 inches high. This will bring down from 8 to 10 feet thick, the parting being called hardstone. The stint for cutting is 3 yards long, and a yard thick, 27 feet on an average. "One such stint is called a day's work, whatever number of hours it may take to perform it. Thus, supposing work plentiful, and the coal of a soft quality and easy to work, a man may do 8 or 9 days' work in a week; or if there is not a brisk demand for coal, he may get through his day's work in 8 or 9 hours, and have the rest of the day at his own disposal. This it is which makes the employment of a pikeman to be generally considered in ordinary times the best, and the object of the ambition of the young and vigorous miner, though it is evident on looking at the view, from the position in which the pikemen are represented, and the confined space and constrained attitude in which they have to wield their picks, that 8 or 9 hours of such work is as much as ordinary strength can support. Still more evident is this to any one personally visiting a mine, and seeing their naked and reeking bodies shining with the sweat, as if oiled; excepting where a coating of dust from the coal mixing with the perspiration has formed a crust on the skin. In the close atmosphere caused by the animal heat, added to that of the candles, and to that due to the depth of the mine, the rapid blows of the picks are intermingled with suppressed groans, such as are uttered by paviours in England, or by woodcutters in France, proceeding from the labourers seated far in beneath the impending mass of coals, giving a vivid idea of the great physical exertion to which every muscle is urged."

The next class of miners to the pikemen, are the various labourers comprised under the general name of *bandsmen* or *bondsmen*, from the circumstance of their working in connexion with the *band* or flat rope, by which the coal, &c. is hoisted to the surface. These men work by the day of 12 hours, and are usually not *stinted*, or paid by the piece. Their various occupations are shown in the large underground view. The *turners out* break the huge masses of coal which have fallen into manageable sized pieces, which the *loaders* place upon the skips, and the *pitchers*, lads of 12 to 15, arrange and surround with iron hoops, which the *horse drivers* then take away to the bottom of the shaft along iron tram-ways, where the *hanger-on* attaches it to the hook and rope, or chain, by which the engine hoists the load to the surface. In the process of holing out the coal, or undermining it, and afterwards at each successive fall of coal, a quantity of small dust coal, in general not thought worth raising to the surface, is produced. It is called *slack*. It is the office of certain stout boys, called *dirt carriers*, to carry this back in baskets or iron trays with handles from where the men are working, to the empty space behind them, commonly called the *gob*. Behind these dirt

COAL.—BRADLEY MINE, NEAR BILSTON. (GETTING OUT THE TEN-YARD COAL IN THE STAFFORDSHIRE COLLIERIES.)

carriers, there is the *clanser* or *cleanser*, who separates the stony partings from the coal where they occur, and builds them up in the gob.

The following account of a visit by Mr. Tancred to the Heath Colliery, West Bromwich, will form an appropriate conclusion to this notice of the thick coal of Staffordshire.

"This pit is very interesting in a geological point of view, having been the first attempt to find the ten-yard coal beneath the lower new red sandstone, by which this coal-field was till then commonly supposed to be bounded on three sides. This attempt therefore having been successful, corresponds in importance to the finding the Durham coal extending beneath the magnesian limestone. The sinking was so expensive here, that there is but one shaft for winding, and one for pumping, which is not advantageous for the engine, as there is no counterpoise of one skip going down, and the full one up. There is an engine of 50-horse power for pumping, and a 30-horse for drawing coals; 30 cwt. is about the average lift of coal, which is raised in 4 minutes, and the skip returned in 3 more.

"On arriving at the bottom, we found quite a summer temperature from the depth, 308 yards. It is very dry, and the main-gate or road is lighted with candles permanently fixed along the sides, an expense which butties do not usually allow, but which is said to prevent accidents. The horses did not seem any way ill-used, as it is said they would be if they were not the butty's own property; one had an eye knocked out, but it was purely accidental; and they showed me how they understood their work just like human beings. The coal here is dragged by a pair of horses on a sledge, from the place where the skip is loaded to the main road. In the main road is a wagon, as it is called, being a square truck running on four low iron wheels, on a tram-road. This tram-road being much below the level of the ground on each side, by just about the height of the little wagon, the skip of coal, which is dragged along like a sledge, is drawn across the road where the wagon stands, and so slides on to the wagon. One horse now draws what two had done, and the last part of the journey it is let to run by itself towards the shaft down an inclned plane, being checked by being hooked on to an endless chain, which, as it runs round a roller, is stopped with a break by a man stationed at the top of the descent for that purpose.

"We saw a large extent of coal *undergone*, that is, the first two operations performed, and the two lowermost strata of coal got out: these are the benches, divided from the next by the bench bat; and the second, slipper and sawyer, the first holed out, the next cut down, leaving a space of 6 feet 6 inches or 7 feet between the floor and our heads. The cleanser was carrying away the heavy *hardstone* which divides the fourth and fifth seam, from some coal which had very lately fallen, before the band or bondsmen came to fill it into the skips. In other places, we saw the turner-out breaking up the great masses of many tons weight of coal into manageable bits, and the labourers, or *band*, filling the coal with hands or shovels into the pit.—We saw a great quantity of coal *undergone*, that is, the first two or three strata to the height of 7 feet taken out, so that the rest had only to be *cut*, or separated at the sides from the pillars, which are left to support the roof, in order to be brought down. When a quantity of coal has fallen after the first holing, it affords a footing to the pikemen, from which they are able to reach high enough to cut into the next stratum. When the height becomes too great, they are obliged to fix scaffolding to reach their work: and so this cutting is much more severe labour than holing, and they often take off their trowsers and work quite naked, the sweat streaming off their bodies like rain, as a pikeman expressed it, and of course the coal dust adhering to the whole person, as it does, indeed, when he is only naked to the waist. It is particularly hard work from the heat which is experienced when half the body is confined during such violent exertion between the two masses of coal, only just wide enough apart to allow the play of the arms, and where the heat is very great from the air not reaching into such places. To understand this cutting, suppose the ceiling of a room were a stratum of coal, like that called *strong coal*, nearly 4 feet thick. The pikeman begins to dig his pick in, and by repeated blows upwards, to cut a channel about 1 foot wide up against the side of the wall. Now if he were to cut all along the whole length of the room and deep enough, the ceiling would have no support, and would consequently give way and fall, crushing all living things beneath it. He therefore leaves, at every 6 feet, perhaps, part of the coal uncut, called *spurns*, which act as supports to the mass something like corbels supporting the beams of a roof, or flying buttresses in gothic architecture. When the pikeman has cut away a channel a foot broad, and so deep that he cannot any longer use his pick with effect, he is obliged to enlarge the lower edge of his cutting, but the deepest part he keeps as narrow as possible, to save labour. As he must keep his wall on one side perpendicular, the channel is straight on one side, and on the side of the coal which is to fall it slopes towards the wall, as in Fig. 585. Having been cut through to the full thickness of the strong coal, viz 4 feet, on both sides of the mass to be brought down, and spurns being left at proper intervals to keep it up whilst the men are at work at cutting, the next operation is to take away these spurns and so let the coal fall, which is called *throwing* the coal. This service is one of danger, and requires much experience and skill. The spurns are cut and pulled to pieces with long-handled instruments called prickers, and the men must often spring back if there is an appearance of the mass coming down. This business of throwing the coal is often done by a few men at night, to prevent danger to the rest.[1] The different sorts of cutting, according to the height of the strata

(1) The danger to the men after this throwing or falling of the coal, is thus explained by one of the witnesses. It should, however, be remarked that the *doggy* is the foreman of the pikemen, and that the *butty* is the middle-man, who takes the contract for a piece of work from the proprietors, and gives it out to the men. "After a fall of coal, it's worse than a field of battle full of soldiers

above the floor of the mine, and the holing, as well as driving the air-courses or gate, roading, &c., are done by different stints or measured quantities, according to their difficulty. The pikemen universally prefer holing as the easiest work, though in this they have to sit on the ground in a place only 2 feet 3 or 4 inches high, where they cannot straighten their neck, far in beneath a mass of coal some 28 feet thick. There you may stoop down and by the glimmer of their candles see them, naked to the waist, plying their picks, their bodies smoking and appearing as if oiled with the perspiration, and a coat of coal-dust adhering to the skin and hair of the head. All the time you hear, issuing from this low-roofed cavern which they are hewing out, stifled groans, which they utter as they rapidly repeat the blows of their sharp picks against the black mass, which is splintered and flies in all directions. The various works going forward in these subterranean avenues produce a development of the muscles of the chest, back, and arms, which could not have been surpassed in the athletæ, who won the laurel-wreaths at the Grecian games. The noxious gases which they are now and then subject to inhale, produce paleness and loss of appetite; otherwise, were it not for the direful accidents to which they are exposed, the thick-coal miners could not be surpassed in healthiness by any other class of workmen. The exhausting nature of their labour doubtless requires for its performance the vigour of manhood still unimpaired by the advance of old age, and a nutritive diet to recruit the frame; but with these conditions, the healthiness of the occupation is proved by recoveries from appalling accidents, which to surgeons unaccustomed to practise amongst colliers appear miraculous.

"The ventilation of this mine is cleverly managed by means of a tunnel extending from the pumping shaft, under the boiler furnace, to the stalk of the furnace fires, by which a very strong current of air is always drawn from the mine. For the ventilation below ground, narrow galleries are cut in the coal, used only as air courses, and there are no boys employed to keep air-doors."

The accidents in the thick-coal pits are very numerous. According to one return, for every 100 men employed 72 accidents occur annually, of which five are fatal. The accidents are almost entirely bruises and broken limbs, arising from the falling down of the coal and heavy materials of the mine. These accidents can only be obviated by a safer system of extracting the minerals by a liberal supply of timber and lights, and by prudence and caution on the part of the workmen and overlookers. Such accidents are most numerous in mines where middle men or *butties* are allowed: they take the contract for a piece of work from the proprietor and give it out to the men, and it is their interest to do the work as cheaply as possible, without any regard to the safety of the men. A few honourable exceptions are, however, mentioned in the Parliamentary Report. One of these is the case of a religious and conscientious man named Mason, whose pit had for a long period been almost entirely free from accidents, and the reason assigned by the men was, that they met together to pray every day in the dinner hour. "About one o'clock the drink goes down the pit, and if a man is not at the place of prayer in 10 minutes after, he forfeits his drink. They sing and pray, and ask a blessing on what they are going to have, and then they sit down in the road and eat their dinner and drink the beer, and after dinner one reads out of the Scripture and explains it, and tells the others what the preacher has said about it. Sometimes they get God's Spirit amongst them very much, and sometimes less so." Very few of these men could read, and it was stated that, "a man would not be allowed to join in singing and praying unless he was thought to be living as a man ought to do."

There are very few accidents arising from explosions of fire-damp, as this gas appears to be engendered by the Staffordshire coal much less abundantly than in most other fields, and that which is produced is carried off by the ventilation. The men work with open candles.

We come now to notice the methods of working coal-mines in other parts of Great Britain, deriving our information chiefly from the valuable reports which have already supplied us with much information on this very important subject.[1] The following statements will be understood to refer to the condition of the mines previous to the passing of the Act of Parliament (5 & 6 Vict. c. 99); since which the evils complained of have been greatly mitigated.

It may readily be supposed that the nature of the employment and the condition of the miner, must to a great extent depend on the thickness of the seam of coal, and the consequent dimensions of the subterranean roadways, together with the ventilation, drainage, and temperature of the mine. These dimensions and facilities must of necessity greatly vary when it is considered that the seams of coal actually worked in various parts of the kingdom, vary from 10 inches to 10 yards in thickness. When the seams of coal are thick, the roads made for conveying the coal from the

to be forced to go to draw the coals before it's settled and made secure. And, perhaps, the doggies will say, 'Go in, we must have these coals drawn out.' That man you were with in our pit, [the doggy,] is as worthy a man as ever stood in shoe-leather, and would not put a man to work in a place that he did not know was safe for any thing. It's always made secure for us."

Another witness says:—"I was working last night at throwing coal. It's safer at night, because when the horses, and rings, and skips are making a noise you cannot hear the coal when it begins to stir. If this had been done in the day, and the band perhaps waiting for it, the butties will not give a man time to prick it with the long prickers, but will say, 'Come, bring the band here, I see it's safe,' and perhaps a piece falls and kills a man. When I worked at Hooker Hill in Tipton, I remember a man being killed by the band being hurried under the stuff where the roof was rotten, and a piece of rock fell on him and knocked a hole in his side. . . I really think if they had looked before they ordered the band in, this man's life might have been saved. The doggy in our pit is a very good one for that; he'll come up to tell you to mind to be careful, and he will have timber up to it."

(1) Reports from Commissioners, 1843. Midland Mining Commission. First Report—South Staffordshire.— —Children's Employment Commission. First Report—Mines, 1842.

workings to the foot of the shaft are always spacious. Little difference will be felt in seams of different thickness, as long as this is not less than from 5 to 6 feet; but as the thickness of the seam diminishes, it rapidly becomes more expensive in proportion to the quantity of coal to be procured, to make the roads for carrying on the operations of the mine of a convenient height, and the cost of doing this is materially affected by the nature of the strata both above and below the seam. If the seam be very thin and the coal of excellent quality, and the strata above and below of such a nature that they cannot be removed without great expense, the roads are in such case made no higher than are absolutely necessary for getting the coal and conveying it to the foot of the shaft. Under such circumstances the operations of the miner are most laborious and injurious.

It is stated that no coal-mine can be worked with tolerable convenience or comfort to the work-people, if the main roads are less than from 5 to 6 feet in height, and the side roads $2\frac{1}{2}$ feet. When the roads are 6 feet high and upwards, there is ample space for carrying on the operations of the mine, and horses can be used for drawing the coals from the workings to the foot of the shaft. When the main roads are $4\frac{1}{2}$ feet high the mine may still be rendered sufficiently convenient for the work-people, and ponies or asses may be employed for drawing the coals. But when the main ways are under 4 feet, the coals can no longer be conveyed by ponies or asses, or even by adult or young men: they can only be conveyed by children. It appears, however, that in many mines the main gates are only from 24 to 30 *inches* high, and in some parts of these mines the passages do not exceed 18 inches in height. In such a case very young children are employed, and even they must work in a bent position of the body.

In the West Riding of Yorkshire children are employed in attending to the trap doors, driving the horses along the main gates, attending to the jenny, and conveying the coals from the bank faces to the shaft where there are no horses, and to the tram-roads where there are any. " The trappers sit in a little hole scooped out for them in the side of the gates behind each door, where they sit with a string in their hands attached to the door, and pull it open the moment they hear the corves (carriages for conveying the coal) at hand, and the moment it has passed they let the door fall to, which it does of its own weight. If anything impedes the shutting of the door, they remove it, or, if unable to do so, run to the nearest man to get him to do it for them. They have nothing else to do; but as their office must be performed from the repassing of the first to the passing of the last

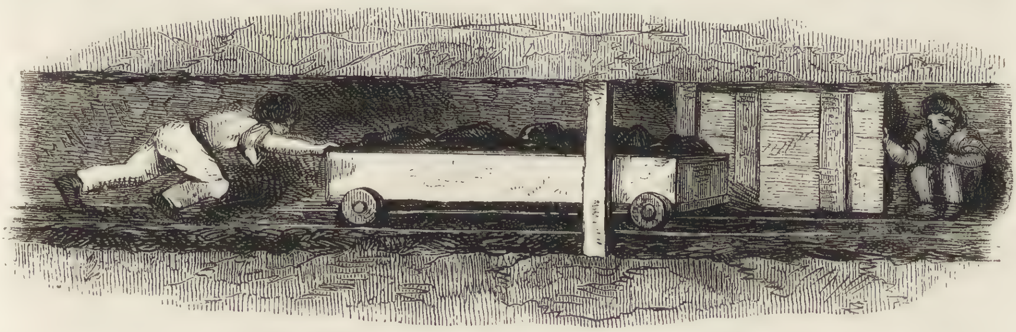


Fig. 586. TRAPPER IN THE LANCASHIRE AND CHESHIRE COAL-PITS.

corve during the day, they are in the pit the whole time it is worked, frequently above 12 hours a-day. They sit, moreover, in the dark, often with a damp floor to stand on, and exposed, necessarily, to drafts. It is a most painful thing to contemplate the dull dungeon-like life these little creatures are doomed to spend,—a life for the most part passed in solitude, damp, and darkness. They are allowed no light, but sometimes a good-natured collier will bestow a little bit of candle on them, as a treat. On one occasion as I was passing a little trapper, he begged me for a little grease from my candle. I found that the poor child had scooped out a hole in a great stone, and having obtained a wick, had manufactured a rude sort of lamp; and that he kept it going as well as he could by begging contributions of melted tallow from the candles of any Samaritan passers-by. To be in the dark, in fact, seemed to be the great grievance with all of them. Occasionally they are so posted as to be near the shaft, where they can sometimes run and enliven themselves with a view of the corves going up with the coals, or perhaps, occasionally, with a bird's-eye peep at the daylight itself; their main amusement is that, however, of seeing the corves pass along the gates at their posts. When we consider the very trifling cost at which these little creatures might be supplied with a light, as is the case in the Cumberland collieries, there are few things which more strongly indicate the neglect of their comfort than the fact of their being kept in darkness,—of all things the most wearisome to a young child."[1]

The chief employment of young persons in the coal mines of this district is to convey the coals in corves either from the workings to the horse-ways, or where the main-roads are not high enough for horses, to the foot of the shaft. The corves are oblong wagons on small wheels of 9 or 12 inches in diameter, running on railways. They vary in size, carrying from 2 to 10 cwt. of coal, but the commonest size in the thickest beds of coal are made to hold 6 cwt. of

(1) Report of J. C. Symons, Esq.

coal, and weigh about 2 or $2\frac{1}{2}$ cwt. themselves, making a weight of about 8 cwt. in all. The operation of propelling these corves is called *hurrying*, and in some places *tramming:* it is done by placing both hands on the top rail of the back of the corve, and pushing it forward, running as fast as the degree of inclination of the road, or the strength of the hurrier, will permit. The hurriers are hired and paid by the colliers; they are often girls of all ages, from 7 to 21. Their work is not confined to the hurrying of the corves backwards and forwards along the gates. When the hurrier arrives with his or her empty corve at the bank-face, it has to be filled; and when the coal has to be riddled or sieved, the hurriers assist. The collier shovels up the smaller coal and throws it into the riddle, which is held by the hurrier, who then shakes it, and throws the coal which remains into the corve. When this is nearly filled it is *topped* with large coal, and the hurrier then starts and hurries it down to its destination, and returns back again as soon as possible with an empty corve. Sometimes when the collier has not got sufficient coal by the time the hurrier returns, the hurrier takes the pick with which the coal is hewn, and helps to *get*. By this means the art of getting is usually learnt, and the hurrier by degrees becomes a collier, and at 18 or 19 leaves off hurrying altogether. Getting is performed first by making a horizontal cut underneath the coal it is intended to get; this is called *holing*, and as it has to be done very low down, the collier is obliged to kneel, and often to lie on one side in a very constrained posture, to work; next, deep vertical cuts are made in order to release the block from either side at given lengths: it is then detached from above by means either of gunpowder or wedges. Girls regularly perform all the various offices of trapping, hurrying, filling, riddling, topping, and occasionally getting.

The seams in many of the mines about Halifax are not more than 14 inches in thickness, and rarely exceed 30. The colliers are obliged to work lying their whole length along the uneven floor, and supporting their heads upon a board or short crutch. When they are able to obtain a little more space, they work sitting upon one heel, balancing their persons by extending the other. In these low, dark, heated and dismal chambers, they work perfectly naked. The corves drawn by the hurriers weigh from 2 to 5 cwt: they are mounted on four cast-iron wheels, 5 inches in diameter, but not moving on rails. These corves are dragged by children through passages in some cases not more than from 16 to 20 inches in height: they buckle round their naked persons a broad leather strap, which is attached in front to a ring and about 4 feet of chain, terminating in a hook. Fig. 587

Fig. 587. A HURRIER IN A HALIFAX COAL-PIT.

In the Derbyshire coal-mines, the girdle and chain form what is called a *dog-belt*. In the pits about Brampton, the seams are so thin that several have only a two-feet headway to all the workings. The pits are worked entirely by boys; the elder one lies on his side, and in that posture *holes* and *gets* the coal, which is then loaded in a barrow or tub, and drawn along the bank to the pit-mouth by boys of from 8 to 12 years on all-fours with a dog-belt and chain, the passages being often an inch or two thick in black mud, and are neither ironed nor wooded.

In the Coalbrook Dale district, the seams of coal are so thin as to afford a striking contrast to the depth of those of South Staffordshire. Boys are employed with the girdle and chain.

In some of the mines of South Gloucestershire, the seams are so thin and the space for working so small, that young lads are employed in hewing coal whose size is suited to the contracted space. In the narrowest seams, the coal comes out in blocks of regular thickness, requiring only the clearance of the clods above and below it, o that it is wrought with little labour, and the small stature of the cutters enables them to perform their task with comparative ease. The lads who hurry the coal wear a scull-cap, *a*, Fig. 588, with a leathern band round it, in which

Fig. 588.

the candle-holder, *b*, is thrust. This holder is a socket of iron, with a spike at right angles for sticking in the sides of the pit when stationary. *c* is a girdle and hook for attaching to the chain.

In Lancashire and Cheshire, the seams are very thin, and young children are employed. Fig. 589 represents three children hurrying a loaded wagon of coals. The child in front is harnessed by the

belt or chain, and is drawing, while the two behind are pushing. Their heads are brought down to a level with the wagon, and their bodies are almost horizontal. This position is necessary to avoid striking the roof, and also to be able to apply their muscular force to the greatest advantage. The boy in front goes on his hands and feet, and the whole weight of his body is supported by the chain attached to the wagon, and his feet, so that his power of drawing is greater than if he crawled on his knees. These

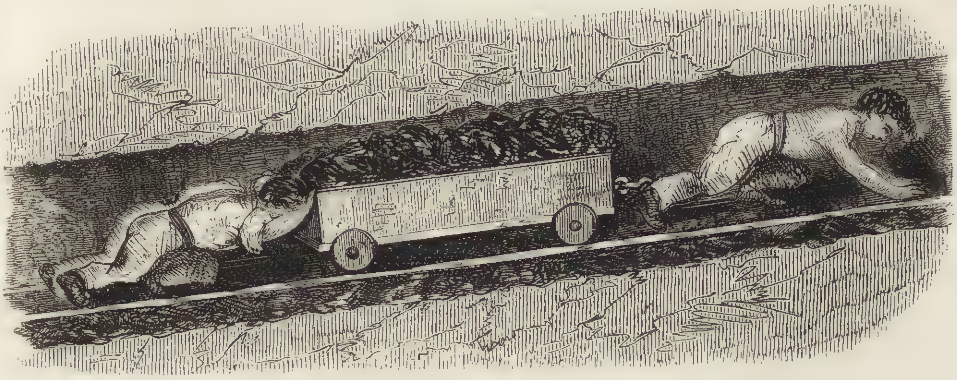


Fig. 589. HURRIERS IN A LANCASHIRE COAL-PIT.

boys, by constantly pushing against the wagons occasionally rub the hair from the crowns of their heads, and become almost bald. The little trapper represented in Fig. 586 belongs to the mines of this district: he is in the act of opening an air-door in a thin mine, to allow a wagon to pass through. The child is represented as sitting on his heels, a common custom with the colliers of this district.

The mines in the mountain seams in the higher parts of Oldham and Rochdale are with few exceptions worked on a very small scale, and in a very rude manner. Several of them are entered by *breast-eyes* or *day-holes* in the hill-side. Many of them are insufficiently drained, and the ways are so low, that only very little boys can work in them, which they do in a state of nudity, and often in mud and water, dragging sledges with tubs of coal on them by means of the girdle and chain, and in an atmosphere and with an amount of ventilation which prove sufficient only because the deleterious gases of the coal-pit are here almost unknown. The main way in the larger mines where the young people have to work, is only $3\frac{1}{2}$ or 4 feet high, and in some cases 6 inches higher; but in narrow seams the height is only 1 foot 10 inches, and the width only just enough for the passage of the tub. A candle stuck in the drawer's cap or in front of the tub, is the only method of lighting these dark and narrow passages.

In Cumberland, the height of the coal-seams admits of horses being brought up to the workings.

In the east of Scotland, from the very great inclination of the strata, the seams are called *edge-seams*, as if they were set up on edge, instead of being horizontal or nearly so. In these mines, girls and women are employed equally with males in all the labour of the coal-mine. It is stated as a general rule, that girls are invariably set at an earlier age than boys to this kind of labour, from a notion among parents that girls are more acute, and capable of making themselves useful at an earlier age than boys. They are engaged in *trapping*, *coal-bearing*, *putting*, *pumping*, and *hewing*. The coal-bearers are almost all girls and women; they carry the coal on their backs, in burdens varying from $\frac{3}{4}$ cwt. to 3 cwt. The following statement will show the amount of labour which a child of tender age has to undergo. The child has to descend a nine-ladder pit to the first rest, where a shaft is sunk to draw up the baskets or tubs of coal filled by the bearers; she then takes her creel, a basket formed to the back, not unlike a cockle-shell, flattened towards the neck so as to allow lumps of coal to rest on the back of the neck and shoulders, and pursues her journey to the wall-face, or *room of work*, as it is called. She then lays down her basket, into which the coal is rolled, and it is frequently more than one man can do to lift the burden on her back. The tugs or straps are placed over the forehead, and the body bent in a

Fig. 590. COAL-BEARING IN THE EAST SCOTLAND MINES.

semicircular form, in order to stiffen the arch Large lumps of coal are then placed on the neck

and she then commences her journey with her burden to the pit-bottom, first hanging her lamp to the cloth crossing her head. One girl noticed by the commissioner had first to travel about 14 fathoms (84 feet) from the wall face to the first ladder, which is 18 feet high: leaving the first ladder, she proceeded along the main road, probably $3\frac{1}{2}$ to $4\frac{1}{2}$ feet high, to the second ladder, 18 feet high; so on to the third and fourth ladders till she reached the pit bottom, where she casts her load varying from 1 cwt to $1\frac{1}{2}$ cwt into the tub. This one journey is called a *rake:* the height ascended, and the distance along the roads, added together, exceed the height of St. Paul's Cathedral, and it not unfrequently happens that the tugs break, and the load falls upon those females who are following. (See Fig. 590.) Figs. 591, 592, 593, will give some idea of the appearance of the coal-bearers and of the passages they have to traverse.

Fig. 591.

Fig. 592.

Fig. 593. TURNPIKE STAIR.

After adducing evidence of the frightful evils resulting from this employment, the sub-commissioner says:—"When the nature of this horrible labour is taken into consideration, its extreme severity, its regular duration of from 12 to 14 hours daily, which once a-week at least is extended through the whole of the night; the damp, heated, and unwholesome atmosphere in which the work is carried on; the tender age and sex of the workers: when it is considered that such labour is performed not in isolated instances selected to excite compassion, but that it may be truly regarded as the type of the every-day existence of hundreds of our fellow-creatures,—a picture is presented of deadly physical oppression, and systematic slavery, of which I conscientiously believe no one unacquainted with such facts would credit the existence in the British dominions."

It is further painful to reflect that all this suffering results from the coal-owners continuing to work their mines in modes which have become obsolete in all other districts. "A little reflection would have prevented a vast deal of unnecessary and painful labour in the working of edge-seams in Scotland; for instance, in South Wales (where the stratification is almost vertical), on the sea coast, at Briton-ferry, and in the Anthracite field in Pembrokeshire, *coal-bearing* as practised in Scotland is entirely unknown. The coal is transported from the different workings by successive windlasses, or balances working on inclined planes, which plan entirely removes the necessity of employing female labour. In the county of Pembroke, for example, the field or bed of coal (anthracite) is in many workings highly inclined. Suppose a vein to lie at an angle of 45° or even 55°, windlasses are fixed at convenient distances on the incline of the vein, by which means (if the mine is worked by adit or level, and *above* the adit) the coal after being brought from the stalls to the stage of the windlass in carts or skips, is dropped by the chain of the windlass down the incline to the level road, and the empty carts are worked up to the stage on which the windlass is fixed by the opposite chain of the windlass. If, on the contrary, the coal is worked to the dip, the coal is in a similar manner worked *up* to a convenient stage by windlass, and then taken by shaft to the surface. The windlasses are worked by women, and their labour is certainly severe, though only of 8 or 10 hours'

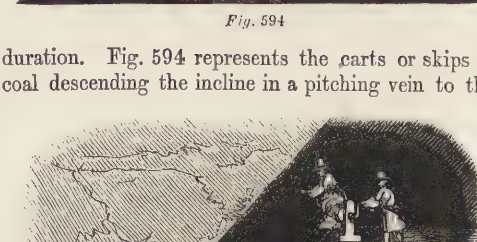


Fig. 594

duration. Fig. 594 represents the carts or skips of coal descending the incline in a pitching vein to the

Fig. 595.

level of the road, after their arrival at which they are drawn by horses to the shaft, or to the mouth of a level. Fig. 595 represents girls winding coal from the workings in the dip.

The Act of Parliament already referred to has put an end to these evils. From the time of passing the Act, no female, other than such as were so employed previously, was to work in any mine or colliery; and after three months from that date, no female under eighteen years old should be so employed; nor any female whatever after March 1, 1843. After this latter date, no males were to be employed under ten years of age; no person to be apprenticed under ten years of age, nor for longer than eight years (except in the case of engine-wrights and others who are only occasionally at work under-ground). Where there are vertical or other shafts, no steam or other engine to be entrusted to the care of a person under the age of fifteen; in the case of a windlass or gin, worked by a horse or other animal, the driver to be considered the person in charge. After three months from the passing of the Act, proprietors of mines or collieries not to pay workmen their wages at any tavern or public-house. To enforce the observance of these regulations the following arrangements were made:—Inspectors of mines and collieries, appointed by the Secretary of State for the Home Department, are empowered to enter and examine any such works, and to report concerning them to the Government; any proprietor violating the law as to the age and duration of apprenticeship is subjected to a fine varying from 5*l.* to 10*l.*; parents or guardians misrepresenting the age of children so employed, are fined 40*s.*; a neglect of the clause as to the care of the shafts, and also of that relating to the payment of wages, subjects the offender to fines varying from 5*l.* to 50*l.*

In many of the coal-mines of England where fire-damp is not very common, ventilation is defective. According to the evidence of Mr. Woodhouse, mining overseer of the Moira collieries, Leicestershire, there are many drawbacks from the profits of collieries arising from a bad and defective system of ventilation. He says:—"The improved system adopted in the collieries on the Tyne and the Wear, of dividing the workings into districts, and so obtaining a current of fresh air in every division, may in many cases be adopted at a trifling expense in these counties; and although the extent of the workings in general bears no proportion to those in the collieries in the north, the principle remains the same, and the result would be favourable in a corresponding degree. It may be urged that the immense quantity of gas given out of the coal in the north has called for the improved system there, which is, probably, the fact; but there are many advantages to be derived from good ventilation, beyond the mere prevention of explosion. In pits with a rapid circulation the men respire more freely, the road ways are kept dry and repaired at less expense, and the timber lasts longer *by years*, and therefore it is a matter of strict economy to ensure a good ventilation. The men suffer most materially from working in an impure atmosphere. In some mines the air can scarcely be perceived to move at all, a thick mist or fog pervading the whole pit; which is caused partly from fermentation in the wastes and old works, partly from the lights, and partly from the heat and effluvia from the horses and men. This, with a large proportion of carbonic acid gas, forms an atmosphere that none but colliers, who are accustomed to it, could endure, but which has the effect of shortening their days."

With respect to *drainage*, some pits are naturally very dry; others cannot be kept so without constant care, and much expense. Various methods of drainage are adopted, according to circumstances; such as bringing up the water to the surface in buts worked by machinery, or by successive lifts of pumps, or by collecting the water in a sink or sump at the bottom of one of the shafts, and then drawing it up in buckets by the engine when it is not engaged in raising coals; or by sinking a shaft on purpose, in which is placed a series of pumps for raising the water from one lift to another, until from the highest pump of all, which brings water to the surface, a perpetual stream is made to flow. Whenever the floor of the pit lies in such a way that the water will flow to the place to which the lowest pump descends, then the pit can be effectually kept dry.

Neglect of drainage renders the mine very miserable for the work-people. Thus, in speaking of the Derbyshire pits, the commissioner says that some of them are so wet, "that the people have to work all day over their shoes in water, at the same time that the water is constantly dripping upon them from the roof. In other pits, instead of dripping, it constantly rains, as the people themselves term it, from the roof, so that in a short time after they commence the labour of the day, their clothes are drenched, and in this state, with their feet also in water, they work all day. The children, especially,—and in general the younger the age the more painfully this unfavourable state of the place of work is felt,—complain bitterly of this, and it must be borne in mind that it is in this district that, according to the evidence, the regular hours of a full day's labour are 14, and occasionally 16." The sub-commissioner, speaking of the same district, says:—"I have met with pits where it rained so as to wet the children to the skin in a few minutes, and at the same time so hot that they could scarcely bear their clothes on to work in, and in this wet state they had to continue 14 hours, and perhaps had to walk a mile or two at night without changing or drying their clothes."

Coal-pits are almost always warm, and in general the deeper they are, the warmer. By proper ventilation the heat can generally be so regulated as to render the temperature pleasant. When cold in the main roads the heat is often oppressive in the side gates and at the workings. Oppressive heat indicates imperfect ventilation. It is stated that in the mines of the Yorkshire coal-fields the thermometer stands in the main roads at from 50° to 60°, in the side roads from 60° to 65°, and at the workings from 64° to 72°. In the deep mines of the northern coal-

field the temperature is considerably higher. In one of the Hetton pits in South Durham, the temperature was found to be 66° at the bottom of the shaft, and 70° in the workings; but in the Monkwearmouth colliery, the deepest in the northern coal-field, the average temperature ranges from 78° to 80°, and in some parts it occasionally rises to 89°.

COBALT occurs in nature in combination with arsenic, as *arsenical cobalt;* or with sulphur and arsenic, as *grey cobalt* ore; but it is also contaminated with iron, nickel, and other metals. The ores remained without value until about the middle of the sixteenth century, when they were first applied for imparting a blue colour to glass; but the nature of the mineral was not known until it was examined by Brandt, in 1733, who obtained from it a new metal, which he named cobalt.[1] Cobalt is also found in most meteoric stones. It is not used in the metallic state: indeed, the processes for its reduction are difficult and complicated, and are carried on only in the laboratory on a small scale. The metal is brittle, of a reddish grey colour, of the density 8.5, somewhat more fusible than iron, and it is attracted by the magnet.

There are two oxides of cobalt: the protoxide, Co O, and the sesqui- or peroxide, $Co_2 O_3$. The former possesses the property of colouring glass blue, even when present in very minute quantity. No other colouring-matter is so permanent or so intense: hence, a glass formed of this oxide, under the name of *smalt*, is of great importance in the arts, it being the blue colouring matter used for ornamenting porcelain and earthenware, for staining glass, for painting on enamel, for tinting writing-paper, and for a variety of other purposes. The interesting processes concerned in the manufacture of smalt will be described presently. The protoxide, which is prepared by igniting the carbonate, is a powder of an ash-grey colour. When precipitated by an alkali from its solution in acids, it forms a hydrate, of a fine blue colour. The salts of this oxide have a reddish colour in solution. This oxide combines with alkalies and earths: dissolved in fused potash, it gives a blue colour to the compound; and when magnesia, or a body containing it, is touched with a drop of nitrate of cobalt, and dried and ignited, a feeble but characteristic rose tint is obtained. A beautiful blue pigment, known as *cobalt blue*, almost equal for purity of tint to ultramarine, is obtained by mixing a solution of a salt of pure cobalt with a solution of pure alum, precipitating the liquid by an alkaline carbonate, washing the precipitate with care, drying and igniting it strongly. A fine green, known as *Rinmann's green*, is similarly prepared, by combining oxide of cobalt with oxide of zinc, or 1 part sulphate of cobalt and 2 or 3 parts sulphate of zinc, dissolving, and precipitating by means of carbonate of soda; and the precipitate, when washed and calcined, acquires a green colour.

Chloride of cobalt is obtained by dissolving the oxide in muriatic acid. The solution is of a pink red, but when highly concentrated, it is of an intense blue. The chloride, the nitrate, and the sulphate of cobalt form what are called *sympathetic inks*. Thus, if characters be written on paper with the chloride, they remain colourless and invisible, or nearly so; but by warming the paper near the fire, the writing becomes of a beautiful blue colour. As the paper cools, moisture is absorbed, and the colour disappears, but may be reproduced by heat. The addition of a salt of nickel gives a green instead of a blue colour. Thus, in painting what are called *magic landscapes*, the sky is painted with pure chloride, and the trees and grass with a solution containing nickel. Nitrate of cobalt forms a red sympathetic ink.

Phosphate of cobalt is an insoluble precipitate, of a deep violet colour. 2 parts of this and 1 part of arseniate of cobalt, carefully mixed with 16 parts of alum and strongly ignited for a considerable time, produce a beautiful blue pigment called *Thenard's blue*. It is said to have all the characters of ultramarine: it has lately been substituted for smalt in the manufacture of paper.

When protoxide of cobalt is calcined with a borax-glass, it absorbs oxygen, and a black mass is obtained, which, mixed with oxide of manganese, forms a fine black, which is used in enamel-painting.

Smalt is principally manufactured in Germany and Norway. In the year 1840, the imports into Great Britain amounted to 118,638lbs., of which 97,751lbs. were from Norway, and the remainder from Germany and Holland. In 1842, the imports amounted to 145,470lbs. By the new tariff an import duty of 10*s*. per cwt. is levied on smalt: this has greatly promoted the sale of a rival colour, artificial ultramarine, which is prepared at a very cheap rate at Cologne and other towns on the Rhine, and being admitted free of duty, it has for the most part superseded smalt for paper-hangings, and all those cases in which it is not used as an enamel colour. The following is a very brief outline[2] of the manufacture of smalt as carried on in Saxony.

The success of this manufacture depends in great measure upon the purity of the materials employed, and on the exact proportions in which they are combined. The ore of cobalt is first picked, to separate stony matters, then sifted, stamped, and washed, by which means it is reduced to a coarse powder, and the earthy matters are separated. The ore is then roasted, for the purpose of separating arsenic and sulphur: this is done in a reverberatory furnace, to which is attached a tube of great length, or a series of chambers for the purpose of condensing the fumes

(1) According to Beckmann, ("History of Inventions," vol. i.) cobalt was dug up in great quantity in the mines on the borders of Saxony and Bohemia, about the end of the fifteenth century. It was thrown aside as a useless mineral, entailing fruitless labour on the miners, and injuring their health by the arsenical particles contained in it. The word *cobalt* is supposed to have been derived from *cobalus*, the name of a spirit which was reputed to haunt mines, destroying the labours of the miners, or giving them much unnecessary trouble. "The miners, perhaps, gave this name to the mineral out of joke, because it thwarted them as much as the supposed spirit, by exciting false hopes, and rendering their labour often fruitless. It was once customary to introduce into the church service a prayer for the protection of miners and their works against *kobolts* and spirits."

(2) Abridged from a paper read by the Editor before the Society of Arts, London, 5th March, 1851.

of arsenic [see ARSENIC]. As an additional precaution, in order to prevent the escape of these fumes as much as possible, the ores in some places, as at Querbach, are roasted only in winter, when, the country being covered with snow, the arsenical vapours cannot injure vegetation, and the low temperature facilitates condensation. The dressed ore (schlich) is wetted, and spread over the sole of the furnace in a layer 5 or 6 inches deep: the heat is then cautiously raised for 6 hours, during which abundant white vapours of water, arsenious and sulphurous acids are evolved: the heat is then increased, and continued for 16, 18, or, at most, 21 hours. The ore is moved about with a rake whenever the vapours cease to be disengaged. Every part of the charge is thus brought under the action of the flame and of the strong draught of air which accompanies it; the object being to expel as much of the arsenic and sulphur as possible, and to convert the cobalt into an oxide. When the vapour ceases to be formed, and the schlich is at a red heat, the operation is terminated, the roasted ore is withdrawn, and the furnace allowed to cool before a fresh charge is put in, otherwise the new ore would become pasty. The quantity of arsenic deposited in the chambers amounts to as much as from 25 to 30 per cent. of good ore: the roasted ore now contains oxide of cobalt, oxide of iron, a small quantity of the arseniate of this metal, together with oxide of lead, titanium, &c.

The sand, or cobaltiferous quartz, which is obtained during the stamping of the ore, is also roasted with some of the dressed ore: it is then sifted, and the pieces which remain in the sieve are pounded, and again roasted. The best ore, when dressed, loses in roasting as much as 50 per cent.; the common ore 40; and the cobaltiferous quartz only 6.

The ores of cobalt, dressed and roasted as above described, are known in commerce under the name of *zaffre* or *saflor*.[1] This substance communicates a magnificent blue colour to glass, and is the chief ingredient in the manufacture of smalt. The other materials,—the silica and the potash,—are also prepared with great care. The silica is obtained by roasting lumps of quartz for 24 or from that to 36 hours; the effect of which is to destroy the cohesion of the quartzose particles. The quartz loses all its transparency, and becomes of a dull white, or yellowish if it contain oxide of iron; it can easily be crushed between the fingers; and the stamping-engine, well supplied with water, readily reduces it to a fine sand. This sand is calcined in a reverberatory furnace, sifted, and then, by repeated washings and decantations, the impurities, consisting of small portions of oxide of iron, lime, and oxide of manganese, are got rid of. The pure sand is finally calcined, to expel moisture, sifted, and stored in boxes for use. The potash is also purified with great care: it is then calcined, and preserved from moisture.

By the combination, by means of heat, of these materials, viz. the roasted ore or zaffre, silica and potash, a *glass of cobalt* is formed, which being pounded, washed, and dried, constitutes *smalt*. But as the particular shade of blue depends upon the exact proportions of the above ingredients, it becomes a matter of considerable delicacy to adjust the relative proportions. The ores of cobalt vary considerably in quality, and the purity of the sand and of the potash may also slightly vary. Hence the manufacturer, before commencing operations on a large scale, makes sundry trials on a small one, and he is able to judge from the results of his small crucibles how to apportion the materials in his glass furnace. Moreover, the manufacturer keeps various samples of smalt of different shades of blue, which serve him as a guide: these samples represent the shades which are known in commerce by certain numbers or letters, such as FC fine, MC middling, OC ordinary, FFFC finest, and so on with a large number of varieties both of zaffre, eschel, and smalt. M. Dumas gives the following recipe for making the shades marked OEG ordinary eschel, in powder or ground, and FOEG fine ditto:—

2½ cwt.	of ordinary roasted ore.
2 ,,	of the roasted mixture of ore and cobaltiferous quartz.
20 ,,	sand.
3½ ,,	eschel or the slightly coloured glass produced by washing the smalt.
10 ,,	potash.
38 cwt.	

The mixture for the smalt marked ME, MC, and FC, is:—

2 cwt.	of the best roasted ore.
5 ,,	sand.
2 ,,	eschel.
4 ,,	potash
13 cwt.	

These ingredients are placed in regular layers in a wooden trough 2 feet deep; first a layer of sand, then a layer of schlich, and thirdly a layer of potash; the whole is then well incorporated by means of a shovel. This mixture is melted in pots, in a furnace similar to that used in the manufacture of GLASS. Each pot contains about ¾ cwt. of material, which is introduced by means of iron ladles, furnished with long handles. New pots are first filled with eschel, for the purpose of coating the interior with a vitreous glaze. In the course of about 8 hours the mixture fuses; the workman occasionally stirring it up with a red-hot iron in order to break up the crust which forms on the surface. The mixture becomes sufficiently fluid to effect a chemical combination of the materials only when the pots are at a white heat. The proper temperature is, in fact, that of an ordinary glass-furnace. If the potash be pure, the scum, which is known as *glass-gall* or *sandiver*, is not formed; but there is usually a portion of this substance to be skimmed off. If the cobalt ore contain nickel, as it usually does, a substance called *speiss* is formed, which, being heavier than the glass, subsides in the

(1) In 1840, this country imported almost entirely from Germany 4,660 cwt. of zaffre. According to the new Customs' Duties, cobalt and zaffre can be imported free of duty; but a duty of 10*s*. per cwt. is levied upon smalt.

Saxony produces annually about 8,000 cwt. of zaffre or smalt; Bohemia 4,000 cwt.; Prussia (Reisengebirge) 600 cwt.; Norway 4,000 cwt.

glass-pot. This speiss is an alloy of cobalt, nickel, iron, arsenic, bismuth, and sometimes silver. This must be separated from the blue glass, which is sometimes done by opening a hole provided for the purpose in the bottom of the glass-pot, and which during the melting is stopped up with clay and sand.

When the blue glass attaches itself to the man's rod, and can be drawn out in threads, it is ready for the next operation, which consists in ladling it out of the glass-pot and pouring it into a vessel full of water, which is kept cool by being constantly renewed. The man is careful not to pour any speiss with the blue glass, for this would injure its colour. All the pots are emptied before a fresh charge is put in, the temperature of the furnace being so greatly lowered by this operation, that it would be impossible but for this precaution to empty the last pot or two of glass.

The blue glass falling at a red heat into water, becomes granular and easy to pulverize. The preparation of this glass powder, however, involves a long series of laborious and curious operations, the science of which has not been very well explained. When the glass is taken out of the water it is drained and crushed in the dry state; then sifted to the size of ordinary sand; it is next ground in mills with granite runners on a granite bed, about $1\frac{1}{2}$ to 2 cwt. of material being wetted and operated on for about 4 or 6 hours. The powder as it comes out of this mill is thrown into large vats full of water; in the course of a few minutes the heaviest portions of the glass, or those richest in cobalt, and consequently finest in colour, subside; this deposit is named *azure.* The water is then drawn off into a second series of vats, and allowed to stand for $\frac{3}{4}$ or from that to $1\frac{1}{2}$ hour, according to the designed quality of the deposit. This deposit is named *Farbe,* the German word for *colour.* The water is again drawn off into reservoirs, where it is left for an indefinite length of time. Here it deposits various kinds of azure, known by the name of *blue sand,* or *Eschel.* The very short space of time required for the deposit of the azure, is subject to variation according to the season of the year. Less time is required in summer, when the water is warmer and less dense than in winter. A portion only of this first quality of azure, named *coarse blue* or *streublau,* is sent into the market in this state: the rest is again ground with a small portion of blue glass. But most of the azure and eschel thus obtained, is subjected to a final washing in tubs abundantly supplied with fresh pure water. The powder is stirred up with proper tools, and is then left to repose: all floating impurities, such as particles of glass-gall, are separated by means of a fine horse-hair sieve. The liquor is then decanted into another vessel, and a fresh portion of powder is subjected to the same treatment. In this way different varieties of smalt are obtained, either in the form of *farbe* or *eschel.*

The results of all these washings are, 1. a deeply coloured azure, 2. a powder *(farbe)* not so deeply coloured, 3. a sand *(eschel)* very little coloured. Dumas supposes that by these repeated washings, a portion of the alkali is removed from the glass, which is thereby brought more into the condition of a supersilicate. This action is most effective on the finer particles; less so on the coarse powder: and as it is essential to impart to the azure the property of retaining its colour in moist air, it has been found that a genuine azure can only be produced from glass of cobalt by repeated washings. This explains why alumina, lime, and bases which tend to make glass of cobalt resist the action of water, should be carefully excluded: arsenic and phosphoric acids tend on the contrary to assist the extraction of the potash, which being in combination with those acids, salts are formed which are more soluble than silicate of potash.

Glass of cobalt appears therefore to be a mixture of different compounds, which may be grouped into two principal varieties: viz. the less fusible silicates in which cobalt prevails, which resist the action of water, and the more fusible silicates in which potash prevails, which are more readily attacked by water. The former constitute *azure,* the latter by the action of water give up to that fluid a subsilicate of potash, and form a supersilicate of potash in a minutely divided state. This, doubtless, explains why it is that azure deepens in colour by the separation of a powder containing very little colour. In fact, the coarse blue powder which is first separated by the action of water is almost identical in composition with glass of cobalt: the azure contains more cobalt but less potash, and the eschel more silica and less potash and cobalt than glass of cobalt. The eschel also contains gelatinous silica, and the waters used in washing it carry away a subsilicate of potash.

The beauty of smalt depends in some degree upon the method of roasting the ore. If the ore is nickeliferous, the roasting must not be carried far; but the ore may be added in certain proportions to well-roasted ore, and the nickel is afterwards separated in the form of speiss.

Smalt may therefore be said to contain silica, potash, cobalt, and arseniate of potash. The last is small and variable in quantity, and its amount depends upon the roasting. It is not an essential ingredient in smalt, but it greatly influences the beauty of the colour. Indeed, according to Dumas, the beauty of smalt depends greatly upon the presence or absence of certain substances in small quantity, such as from 4 to 5 per cent. of arsenic and arsenious acids, 6 to 9 per cent. of phosphoric acid; the colour is also greatly heightened by very small portions of zinc, tin, antimony, and nitre. On the other hand, the tint is weakened or injured by the presence of nickel, lead, or iron beyond 10 per cent., bismuth, borax, soda, alkaline earths, alum, felspar, fluor spar, sulphur, &c.

The following is an example of the mode of manufacturing the variety known by the mark OC (common azure).

The smalt having been reduced to powder, is mixed with water and left for 45 minutes: the water is then drawn off, and there remains at the bottom of the vessel a coarse azure blue, which is a blue glass

in a less minutely divided state than that which remains suspended in the water. The water thus drawn off is left for a much longer time, in order to separate the coloured particles which form azure, from the nearly colourless particles which form eschel. At the end of 36 hours the water appears feebly coloured. It is drawn off into a vessel and left until it is perfectly colourless. It is then thrown away, and the deposit is eschel, which is dried and added to the mixture used in charging the glass-pots.

The azure blue adheres strongly to the vessel in which it is deposited: it is broken up with mallets, and reduced to powder by being passed between cylinders: it is then washed many times in different waters. About 3 cwt. of the colour are put into the vat, the water is then added and the whole stirred up with a wooden tool until the azure is completely suspended: the floating impurities are removed by means of a fine sieve, and the whole is then left for 22 or 24 hours. At the end of this time, the water, still a little coloured by means of eschel, is passed into another vat: the second deposit is taken out and broken up, well mixed with water and then left for 18 or 20 hours; the water is then decanted. The operation is repeated a third time, and the deposit is allowed 16 or 17 hours to form. The water being decanted, the washing is finished. All the shades of azure are treated in the same manner, the only difference being in the time allowed for the deposit, which varies according to the required shade.

All these precipitates are removed from the vats, and being collected are dried in a hot room, or in a room in which the air freely circulates. They dry into compact masses, which are broken up by means of cylinders, or by mills. The produce is then passed through sieves of various degrees of fineness enclosed in boxes, or a bolting-cloth is used. The powder is then dried in a room heated from 100° to 115° by a flue passing under it. The powder is placed in layers 2 or 3 inches thick on raised platforms to dry by the hot air of the room, and is moved about from time to time by means of a rake. 27 cwt. of azure can be dried by this means at one time. When sufficiently dry, the azure is again ground and sifted. It is then compared with the marked and numbered standards already referred to, and its number being assigned to it, it is packed up in small quarter-of-a-hundredweight casks slightly moistened on the inside, and the proper mark and number is marked on the outside.

It is calculated in this long series of minute operations that every 100 quintals of glass of cobalt produce about 60 or 70 quintals of azure blue or coarse blue.

Smalt is used in the manufacture of porcelain, pottery, stained glass, encaustic tiles, fresco-painting, &c.: the paper-maker also employs it to cover the yellow tint of his paper. Berzelius remarks that the silica contained in writing-paper blued by it blunts the nibs of pens. Smalt was formerly used in the manufacture of bank-note paper, and the ash produced by the periodical combustion of notes at the Bank forms a blue vitreous slag, which may often be met with in collections of minerals. Blue-tinted writing-paper leaves a fine blue ash when burnt, and often exhales the peculiar odour of arsenious acid from the presence of this substance in smalt. There is some difficulty in keeping the smalt uniformly suspended in the pulp, and hence the lower side of the sheet is generally bluer than the upper. This defect has led to the use of artificial ultramarine for blueing writing-paper. Cheap ultramarine is also used as a substitute for smalt and Thenard's blue, in producing the brilliant and durable blues of paper-hangings. The celebrated blues of Sèvres porcelain are produced from cobalt dissolved in acids and precipitated.

COCCULUS INDICUS, the fruit or seed of a tree, *Anamirta cocculus,* belonging to the order MENISPERMACEÆ, growing upon the coasts of Malabar, Ceylon, &c. This seed contains the venomous principle *picrotoxine,* and in the pericarp is the poisonous alkaloid *menispermine.* The seed is sometimes thrown into waters for the purpose of intoxicating or killing the fish, and it is said also to be used by some brewers as a substitute for hops, and by publicans for increasing the intoxicating properties of ale or beer.

COCCUS. See GALL INSECT.

COCHINEAL. An important dyeing material composed of the dried bodies of cochineal insects, natives of Mexico, Georgia, South Carolina, and some of the West India islands. The cochineal insect is small, and was long mistaken by Europeans for some kind of grain or seed. It feeds on a kind of cactus (*Cactus cochinellifer*), with small, deep, red flowers. The juice of this plant is supposed to give the colour to the cochineal. The insects are detached from the plants by a blunt knife, put into bags, and dipped in boiling water to kill them. They are then dried in the sun, and again packed in bags (each bag containing about 200 lbs.) for exportation. The appearance of the dye as thus received varies greatly according to circumstances. If the insects are of the fine sort, and have been killed in the manner just stated, they are of a reddish or purplish brown colour; if they have been killed by the heat of an oven, a white powder, with which they are covered when alive, is not removed, and the whole mass of insects appears of an ashen grey. If the insects have died on the trees, they will be of a blackish hue. Cochineal insects are carefully cultivated in plantations of their favourite cactus, but an inferior sort is very common in the woods, feeding on a thorny cactus there. This is called *wild cochineal,* but even when introduced into the plantations it remains inferior, and is sold at a lower price. Wild cochineal yields one-third less colouring matter than fine cochineal. The species of cochineal called *granilla* or dust is supposed to be principally made up of this inferior sort. The demand for the best cochineal during the war was so great that this, together with obstacles in the way of its importation, raised the price from 12*s.* or 13*s.* to 36*s.* and 39*s.* per lb. Since 1814 the price has sunk gradually to from 4*s.* to 6*s.* per lb. And

although lac dye has lately been partially employed for dyeing scarlet, yet the consumption of cochineal is on the increase. In 1840 the quantity entered for home consumption was 510,554 lbs.; in 1841 it amounted to 1,120,655 lbs. The duties on cochineal were reduced in 1842 to 1*s.* per cwt. They had previously been 6*d.* per lb. on foreign, and 2*d.* per lb. on colonial cochineal. In 1846 the duty was entirely repealed. In 1849 the imports amounted to 18,254 cwt. [See CARMINE.]

COCK. See CASTING.

COCO-NUT TREE (*Cocos nucifera*). The great variety of uses to which this tree is applied by the natives of the countries where it grows, and the commercial value of some of its products, render it peculiarly interesting in an industrial point of view. This tree is found in the tropical parts of the world, chiefly in the vicinity of the sea, growing within reach of salt water, and taking root upon reefs and sand banks as soon as they emerge from the ocean. Its principal range is said to be between the equator and the 25th parallel of latitude, and in the equinoctial zone; it will grow at various elevations under about 2,900 feet above the sea level. This tree is sometimes found to occupy extensive tracts to the exclusion of all other trees. The whole Brazilian coast from the river San Francisco to the bar of Mamanguape, a distance of 280 miles, is with a few exceptions thus occupied.

The coco-nut palm rises like a slender column to a height of from 60 to 90 feet. Its stem is soft and fibrous, and it is marked on the outside by rings produced by the fall of its leaves, two of which are said to drop off every year. About 11 or 12 leaves, each from 12 to 14 feet long, form a tuft at the top. The flowers proceed from within a large pointed spathe, which opens on the under side. In wet seasons the tree blossoms every five or six weeks, so that there are often fresh flowers and ripe nuts on the tree at the same time. There are from 5 to 15 nuts in a bunch, and in good soils a tree may produce from 8 to 12 bunches every year.

The *roots* of this tree are sometimes masticated by the natives instead of the areca-nut. The Brazilians make baskets of the small roots. The hard woody *shell*, or crust of the *trunk*, is employed by the natives in making drums, and in the construction of their huts, &c. Towards the base of the trunk, the wood is remarkably hard, and admits of a high polish: a transverse section well polished and varnished, rivals the agate in lustre. The reticulated substance at the base of the *leaf* is in some places formed into a cradle or couch. In Ceylon, it is used for straining the sweet juice which is extracted from the flowering spathe of this tree. It is also manufactured into a durable sackcloth called *gunny*, but according to some, gunny-cloth is made of hemp. The unexpanded *leaves*, or terminal *leaf-bud*, is occasionally eaten by Europeans, as well as by natives. When boiled it is tender, and forms a good substitute for cabbage. The natives sometimes preserve it in vinegar, and eat it as a pickle. The tree, however, dies when this part is removed. The natives thatch their houses with the *leaves*, for which purpose, the central ligneous portion of the leaf is divided longitudinally; the leaflets of each half are then plaited or interwoven, and in this state they are employed to thatch cottages, to shelter young plants from the scorching rays of the sun, to construct fences, to form the ceiling of rooms, and to make baskets for carrying fruit, fish, &c. Sometimes baskets are made of palm-leaves, so close as to serve the purpose of buckets to draw water from deep wells. The immature leaves of the coco-nut tree have a fine yellow colour, and a beautiful texture resembling fine leather or satin: they are used for decking rooms, &c., and being translucent, they are used for making lanterns. In some islands, the leaflets are plaited into bonnets and hats. They are also used as a substitute for writing-paper, the pen being an iron stile. In this way letters are written, and are then neatly rolled up and sealed with gum-lac. In writing, the leaf is held flat in the left hand, and the letters are scratched upon the surface with the iron point. Instead of moving the hand with which they write towards the right, they move the leaf in a contrary direction, by means of the thumb of the left hand. To render the characters more legible, the engraved lines are frequently filled by besmearing the leaf with fresh cow-dung, and then tinging this substance black; or the lines are rubbed over with coco-nut oil, or a mixture of oil and charcoal powder. Baskets for catching fish, shrimps, &c. are made of the ligneous ribs of the leaflet; these ribs are also formed into pins, tooth-picks, &c., and made into a bundle, they form excellent brooms. With the exception of the framework, every part of a house, walls and roof, is formed of coco-nut leaves; such a house is capable of resisting all kinds of weather for a year or more. A coco-nut leaf fixed along the stem of a fruit-tree, serves as an alarum; as the leaf rustles very much when touched, a thief is cautious of ascending the trunk, lest he should alarm the inmates of the neighbouring huts. In travelling by night, coco-nut leaves are used as torches; by tying the leaflets close to the centre rib of a leaf, the ignition is prevented from being too rapid. Such torches are in constant use to scare away wild beasts, particularly elephants, from cultivated fields. The coco-nut tree, especially the leaves, when burned, affords a large quantity of potash, which is used as a substitute for soap. Boats are rowed with the centre rib of the leaf. The end of this part of the leaf being well bruised, makes an excellent brush, which is used for a variety of purposes. The *spathes*, or fibrous covering of the blossoms, are inflammable, and are often employed as torches. By soaking in water, this part of the tree forms a coarse cordage used for securing the thatch of houses. The *flower* and *fruit* of this tree afford many useful products. By a peculiar manipulation, the flower yields a rich saccharine juice convertible into arrack or sugar. For this purpose, a man named a "toddy-drawer" ascends the tree, cuts off the point of the spadix, and passes a

ligature firmly round the stump. It is then beaten with a stick, which is supposed to determine the sap to the wounded part. This process is repeated for several days, a small portion of the end of the spadix being cut off each day. The juice soon begins to flow from the cut surface of the flower, and is carefully collected in an earthenware vessel suspended from the spathe. A thin portion of the flower and spathe is sliced off daily, and the end of the stump is bound with a ligature. A good healthy blossom will give from 2 to 4 pints English of sweet juice or *suri* daily, and some flowers will continue to yield juice for 4 or 5 weeks. There are frequently 2 spathes on one tree yielding suri at the same time, which by exposure to the air immediately begins to ferment, and forms the intoxicating liquor, *toddy*. By distillation, this juice yields about one-eighth part of arrack, of the same strength as good brandy. The seamen belonging to the Royal Navy in the Indian Seas, are furnished with it instead of rum. By allowing the juice to pass into the acetous fermentation, an excellent vinegar is obtained, in which a great variety of vegetables are pickled. Suri is the yeast commonly used by the bakers in Ceylon.

In order to obtain sugar (*jagery*) from suri instead of spirit, great care must be taken to prevent fermentation. The earthenware pot in which it falls is emptied twice or thrice in the course of 24 hours, and is well cleaned and dried each time; a small quantity of lime is then thrown into it: the juice is filtered through the reticulated substance at the base of the leaf, and then slowly boiled in an earthenware vessel until it becomes light coloured and viscid. While still warm and semifluid, it is poured into sections of coco-nut shells, where it soon becomes solid. A gallon of juice yields about a pound of sugar. Jagery contains both the crystallizable portion of the juice, and a quantity of molasses or liquid sugar; but they are separated by a subsequent operation. This coarse sugar is usually made into small loaves of the shape of a hemispherical vase from the form of the vessel in which it cools. It has a deep chocolate colour, and when broken presents many clear particles of sugar. In the Malay language, jagery is called *goola* or *goora itan*, black sugar or black sweet.[1] Jagery is sold at the rate of about 2*d*. per pound.

Intimately mixed with lime, jagery forms an excellent cement, which resists moisture, and endures great solar heat. It also takes a very fine polish. Walls are prepared for receiving this covering by wetting them with a strong infusion of the husk of unripe cocos, and the same kind of fluid is used for mixing and tempering the materials. In Madras, and other parts of India, the flat tops of the houses are covered with this cement. It is also employed to form the floors of rooms, to cover columns, &c. Floors of this kind are sometimes stained, and made to resemble the finest marble.

(1) The Sanscrit word *goor* signifies *sweet*: the superlative of this word *seogoor*, sweetest, is supposed by some to be the origin of the word sugar.

When the flower has not been injured the tree bears *nuts*, which are converted to many useful purposes; young coco-nuts are much used by the natives as an article of diet. During the unripe state of the fruit the shell is lined with a pulpy substance, while the centre is filled with an aqueous fluid. This fluid is at first slightly astringent, and sub-acid; as the fruit ripens it becomes sweetish and not unlike the colour and consistence of the whey of milk. When drunk before the sun has far advanced it is much cooler than the atmosphere, and is then a pleasant beverage. Natives, particularly when travelling, generally furnish themselves with a few unripe nuts, the water of which they drink, and eat the pulpy portion or kernel. A few meals of this kind will support a labouring man from morning till night, without any other article of diet. The Malays train monkeys to fetch coco-nuts from the trees as they are wanted, and in this occupation they are expert and docile. The native inhabitants of the coasts of some of the islands in the equinoctial zone, procuring their food with so much ease, are little sensible to the ordinary motives which impel mankind to labour. They are more palmivorous than granivorous, and the man who possesses a garden with 12 coco-trees and 2 jack-trees has no call to make any exertion.

The *husk* or fibrous pericarp of the nut is employed to polish furniture and to scour the floors of rooms, &c. Birds that construct pendulous nests commonly employ this substance. Its chief use, however, is in the manufacture of *coir*, and for this purpose the nut ought not to be completely ripe. To remove the husk, an iron spike or sharp piece of hard wood is fixed in the ground; the nut is then forced upon the point, which passes through the fibres and separates the rind from the shell. In this way one man can clear 1,000 nuts daily. Coir is prepared by soaking the rind in water for several months, and then beating it upon a stone with a piece of heavy wood. On the coast of America, when a running stream of water is not near, the coir manufacturers dig holes in the sand below high water-mark, and bury the rind before beating it. It is subsequently rubbed with the hand until the interstitial substance is completely separated from the fibrous portion of the husk. The rind of 40 nuts furnishes about 6 lbs. weight of coir. The next operation is to twist the fibres into yarns, which are manufactured into cordage of all sizes. Coir is remarkably buoyant, and well suited for ropes of large diameter. Sea water is said to be beneficial rather than hurtful to it, and the cordage, when properly prepared, is pliable, smooth, strong, and elastic; it is well adapted for running rigging, but, on account of its contractibility, it is not so well suited for standing rigging. Dr. Roxburgh found the comparative strength of hemp-rope and coir-rope when large to be as 108 to 87, and when small as 65 to 60. The natives sew the planks of their boats together with coir yarns. Coir is much used in India instead of hair, to stuff mattrasses, cushions, saddles, &c. It is also employed to make brooms and brushes for the purpose of whitewashing houses.

The *kernel* of the ripe nut resembles an almond, and is the *bread* of many of the natives. By a little pressure it yields a white fluid, resembling milk, which is used as a substitute for it in tea, &c. Another substitute for milk is obtained by rasping the kernel and mixing the scrapings with some of the liquid contained in the nut, and then straining. In Barbadoes puddings are made of coco-nuts, and when pressed with honey and sugar the kernel is used to make preserves. The ripe nut is also used in Ceylon to furnish an oleaginous fluid required to prepare curry. But the chief product of the kernel is its *oil*, which is extracted either by decoction or expression. In the former process the fresh kernel is finely rasped, the raspings are then washed with water, which becomes milky, and by decoction yields a limpid oil. If the emulsion be exposed for a night, it separates spontaneously into an oily and a watery portion, and the oily portion is purified by a very short boiling. To separate the oil, the operator, who is generally a female, lays the palm of her left hand flat upon the surface of the fluid; a portion of oil adheres to the hand, which is brushed off into a vessel by the right hand. The oil made in this manner is nearly as colourless as water, and when newly prepared has no offensive odour, but if exposed to the air a few days it becomes offensive. 10 nuts yield on an average about a quart of oil, but according to another authority 32 nuts yielded only 3 lbs. of pure oil. When the oil is prepared on a large scale, compression is resorted to. After clearing the nut of the husk, the kernel is exposed, which is effected by breaking the shell with a crooked knife, an operation which is generally performed at one stroke. The watery part of the kernel is dissipated by exposing it to the sun for a few days, during which period it acquires a considerable degree of rancidity. The oil is extracted by grinding the kernel in a very clumsy mill, worked by bullocks; but at Colombo steam-power is used for the purpose. The substance which remains after the oil has been extracted serves well to feed pigs, poultry, &c.

Large quantities of nuts are brought to this country from the West Indies. The captains of ships use them instead of wedges of timber for filling up the vacant spaces between the casks and other packages which compose their cargoes. On this account the freight of the nuts adds little to their original cost.

In Ceylon the oil is used as a lamp oil. The natives burn it in a section of the shell with cotton wicks. Torches are prepared in Siam by drying elephant's dung, soaking it in coco-nut oil, and then covering the mass with long, dry leaves, tied at short distances with shreds of bamboo. The natives also use the oil for anointing their bodies. It is used also instead of olive oil in the preparation of ointments, plasters, &c., and in making mercurial ointment it is said to divide, or *kill*, the mercury better than any other vegetable oil. Melted with resin it forms a substance used for paying the seams of boats and ships, and also for protecting the corks of wine and beer bottles from the depredations of white ants.

The *shells* of coco-nuts are manufactured into beads for rosaries. They are also used as drinking vessels and for various other domestic purposes. Occasionally they are polished by the natives, who cut figures in relief upon them. When thus ornamented they are sometimes employed by the English as sugar basins; and in South America the ladies drink tea out of highly-ornamented coco-nut tea-cups, sucking it through a long silver tube. Ladles are formed of a part of the nut, with a long wooden handle attached. The natives of some of the oriental islands use the shells as measures both for dry and fluid substances. Their capacity is known by the number of cowries they will contain. Hence there are cocos of 500 or 1,000 cowries, and so on. The shells are also used as fuel by the goldsmiths; and when converted into charcoal they are mixed with lime, and employed to colour the walls of houses. Lastly, from various parts of the coco-nut tree the natives prepare many remedies for a variety of diseases.[1]

COFFEE is the seed contained in a berry, the produce of a tree, *Coffea Arabica*, of the order of *Cinchonaceæ*. This tree grows to the height of from 8 to 12 feet, and has long slender branches bending downwards, and furnished with evergreen opposite leaves. The blossoms are white: the fruit is a red berry with a pale, insipid, somewhat glutinous pulp inclosing two hard oval seeds, each about the size of

Fig. 596. THE COFFEE PLANT. (*a*, section across the ripe fruit.)

an ordinary pea. One side of the seed is convex, the other is flat, with a straight furrow inscribed through its longest dimension. While growing, the flat sides of the seeds are towards each other, and they are covered by a cartilaginous membrane called the *parchment*. Coffee requires a warm climate, a new soil, and a gentle slope to prevent water from lodging at the roots. The trees are raised from seed in nurseries, and afterwards transplanted out. They begin to bear at two years old, and in their

(1) Our information has been chiefly derived from a paper inserted in the fifth volume of the "Memoirs of the Wernerian Natural History Society," entitled "Contribution to a Natural and Economical History of the Coco-nut Tree;" by Mr. Henry Marshall, Surgeon to the Forces, &c.

third year are in full bearing. The period of flowering does not last more than two days. In one night the blossoms expand so profusely that the trees appear as if covered with snow. The seeds are known to be ripe when the berries have a dark red colour. In Arabia the planters spread cloths under the trees, and on shaking them the ripe berries drop readily. In the West Indies the berries are picked by the negroes. "In curing coffee it is sometimes usual to expose the berries to the sun's rays in layers, 5 or 6 inches deep, on a platform. The pulp ferments in a few days, and having thus thrown off a strong acidulous moisture, dries gradually during about three weeks. The husks are afterwards separated from the seeds in a mill. Other planters remove the pulp from the seeds as soon as the berries are gathered. The pulping-mill used for this purpose consists of a horizontal fluted roller, turned by a crank, and acting against a movable breast-board, so placed as to prevent the passage of whole berries between itself and the roller. The pulp is then separated from the seeds by washing them, and the latter are spread out in the sun to dry them. It is then necessary to remove the membranous skin or parchment, which is effected by means of heavy rollers running in a trough wherein the seeds are put. This mill is worked by cattle. The seeds are afterwards winnowed to separate the chaff, and if any among them appear to have escaped the action of the roller, they are again passed through the mill."[1]

There are several varieties of the coffee-tree, the result of differences in soil and climate. Arabia is its reputed native country; but the virtues of the berry are said to have been first known in Persia. Its use was for some time checked by the Syrian Government on account of its supposed intoxicating qualities; but it is reported to have been publicly sold at Constantinople in 1554. The first coffee-house in London was opened in George Yard, Lombard Street, by one Pasqua, a Greek, who was brought to London in 1652 by a Turkey merchant named Edwards. About 1699 the quantity of coffee consumed in the United Kingdom was 100 tons a-year, of which 70 were used in England. It was sold in druggists' shops at about 2*s.* 8*d.* per pound.

Coffee is supposed to owe its refreshing character to a peculiar chemical principle, *Caffeine*, which appears to be identical with that obtained from Tea (*Theine*). This substance belongs to the class of azotized basic bodies, and from its presence in two substances so dissimilar as tea and coffee, one or both of which is in such general use all over the world, it may be supposed to be of importance to our animal economy. Liebig has shown that the composition of caffeine ($C_8H_5N_2O_2$) is closely related to that of various animal products, and that there is reason to believe that it may assist in the secretion of bile. A pound of coffee yields by sublimation on an average about 15 grains of caffeine. It may also be obtained from an infusion of raw coffee when certain impurities have been removed by subacetate of lead, and the excess of lead by sulphuretted hydrogen. It forms white silky crystals, which are sparingly soluble in cold water, and in alcohol easily by the addition of heat. It has a mild bitter taste.

The following analysis of coffee berries has been published by Payen:—

Cellulose or woody fibre	34.000
Water	12.000
Fat or oily matter	13.000
Glucose and dextrine (sugar and gum)	15.500
Legumine and caseine	10.000
Chlorogenate of potassa and caffeine	5.000
Azotized substance	3.000
Free caffeine	0.800
Essential oil	0.003
Mineral Substances	6.697
	100.000

The peculiarly refreshing and stimulating properties of coffee are developed in the roasting. According to Cadet, coffee roasted to a pale brown colour loses 12.3 per cent.; to a chestnut brown, 18.5 per cent., and to a black, 23.7 per cent. Schrader found in roasted coffee—

Extractive matter soluble in water and alcohol, closely resembling that of raw coffee, but browner and deliquescent	12.5
Brown gum	10.4
Extractive soluble in water, but insoluble in alcohol	5.7
Oil and resin	2.0
Insoluble burned woody fibre	69.0

A portion of tannine appears to be formed during roasting. "Schrader endeavoured to ascertain the particular principle to which the flavour and aroma of roasted coffee are due, by exposing each of the proximate principles of unroasted coffee separately to heat; but he found that no one of them yielded any peculiar flavour, and that the ligneous residue, when roasted, acquired as much of the characteristic flavour as when the other principles were retained; so that the flavour of the roasted coffee must be ascribed to the joint effect of heat upon all the constituents. The caffeine seems to play a very passive part as far as flavour is concerned, and a considerable proportion of it remains unchanged after roasting, whilst another part of it is merely volatilized.[2]

The usual method of roasting coffee is very simple. A large iron drum containing the coffee is made to revolve over an open fire, as in Fig. 597. The drum is covered with a case or hood, which confines the heat; but when the man wishes to see how the roasting is going on, he throws back this hood, and by turning a handle at the side, lifts the drum completely out of the fire upon two projecting arms which support the axis. Then by opening a sliding door in the drum, the coffee can be examined. At Messrs. Barry's establishment (to which we are indebted for much information, as well as for the pictorial sketches which illustrate this notice, and the previous notices of Chicory and Chocolate) they roast during the winter season about 3 tons of coffee every day. They calculate that the loss in roasting amounts to rather more than one-fifth, but less than one-fourth

(1) Dr. Lankaster: "Vegetable Substances used for the Food of Man."

(2) Brande: "Manual of Chemistry," p. 1470.

of the weight of the green coffee. The vapour of water which is first expelled escapes by an aperture in the axis of the drum. When the roasting is com-

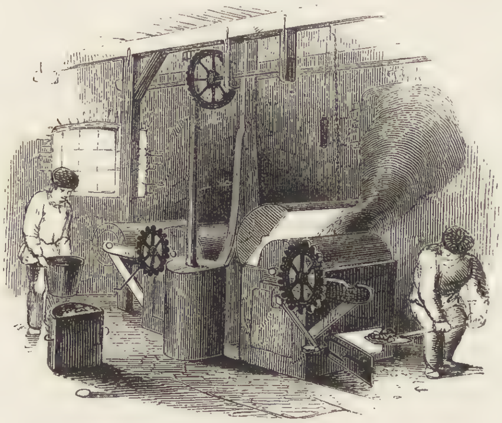


Fig. 597. ROASTING COFFEE.

pleted the berries are turned out into *coolers*, Fig. 598, which are large shallow troughs with wire gauze bottoms suspended between upright posts, and balanced in the centre. These troughs are attached to a bar at the side, which passes up to the projecting arm of a horizontal bar, which is moved through a portion of a circle by the reciprocating action of another bar shown in front of the figure. This causes the troughs to tilt backwards and forwards, by which means the berries are kept in constant motion, and

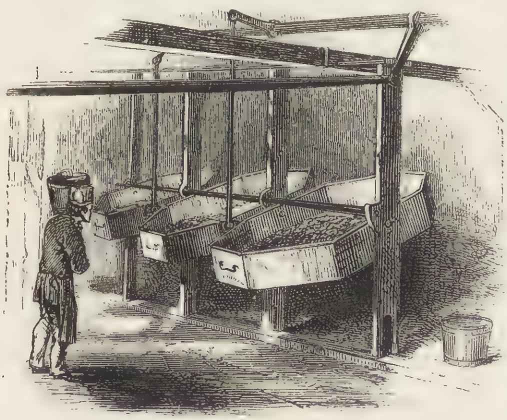


Fig. 598. COFFEE COOLERS.

are freely exposed to the air until they are cold, and any husk or dust is separated, and falls out through the meshes of the wire. This cooling seems to be necessary, for roasted coffee, especially in large quantities, is liable to heat, and to such a degree when ground as to take fire. Some mysterious accidents from fire have been referred to this cause, such as the burning of a frigate in the port of Cronstadt, when no fire had been in her for several days before. M. Georgi roasted a quantity of coffee until brown, and without grinding it tied it up in linen and set it by. No particular result was observed, but when two pounds of roasted coffee were ground to powder and tied up in a similar manner, it took fire and continued to burn until it was reduced to ashes. Similar trials were made with roasted barley and rice, with the same results.

When coffee is roasted, a quantity of water is given off in the form of steam, so that the berries are for a time exposed, at a high temperature, to an atmosphere of watery vapour. Judging from the injurious effects upon many plants used in medicine, of drying them in a confined space where their watery particles cannot freely escape, it seems probable that this confined vapour must be injurious to the coffee. If coffee be heated in a glass mattrass and stirred so as to prevent burning, it soon acquires a very unpleasant odour from the water being confined; but if a sample of the same coffee be roasted on a flat surface exposed to the air, there is no such result. By continuing the heat after the greater part of the water has been expelled, the coffee begins to grow brown, and as the process is continued, it is obvious that the interior of each kernel must be roasted to a less degree than the exterior portion. This under-roasting of the interior produces a raw flavour. If, however, the roasting be continued until the inside is properly done, then the outside will be roasted too much; the consequence of which will be a burnt and bitter flavour. We therefore cordially agree with the suggestion made by Mr. Donovan,[1] that the green coffee be dried in a large shallow iron pan over a very gentle fire, constantly stirring until the colour become yellow: this will dispel the greater part of the water. The berries should then be pounded into coarse fragments, each kernel into 4 or 5 parts for example, and transferred to a close roasting apparatus and roasted to the proper degree. The dealers, to prevent what they think too much loss of weight, commonly under-roast: 16 ounces on an average are reduced to only 14: the berries when ground furnish a brownish powder with a tinge of orange, and the infusion wants the enlivening qualities for which coffee is valued. The greatest number of advantages in roasting, are obtained by reducing 15 ounces to 12 by a very gentle heat. A greater loss than this (which is $\frac{1}{5}$th) produces a bitter flavour, and less than this a raw one. When ground, or even when whole, the colour should be a bright chocolate, and the liquid coffee of a brilliant brown with a tinge of orange.

Those who have leisure to roast their own coffee, may first dry it in a thin layer in a frying-pan over a slow fire, frequently stirring; when all the moisture is expelled, let the roasting be done in a common glass oil-flask: this will roast as much as a quarter of a pound at a time, but it is best to roast only as much as is wanted at one time. The flask will bear the heat of a naked fire without injury, but it should be kept constantly turning round. The common sheet-iron roaster is not only injurious from its confining the vapour, but also from its conducting the heat too quickly. The glass being a bad conductor is free from this latter defect. The common sheet-iron roaster would be greatly improved, if, as Mr. Donovan

(1) Domestic Economy. Vol. II. in Lardner's "Cabinet Cyclopædia."

suggests, it were made double; that is, one cylinder within another, half-an-inch space being left between them. The roaster should never be filled more than one-third, for by roasting the bulk is nearly doubled.

Mr. Donovan proved that grocer's coffee is not sufficiently roasted, by the following experiment. 4 oz. of grocer's ground coffee were boiled in successive pints of water, until the last had scarcely taste or colour: the grounds were then dried before the fire and roasted in an oil flask, and being boiled in a pint of water the decoction had a strong taste of coffee, although it was too bitter.

The question whether coffee should be boiled or infused may be thus answered:—By infusion in boiling water, the aroma is extracted and a portion of the bitter; by long boiling the whole of the bitter is extracted and all the aroma dissipated. Now an excellent method of making good coffee is to put a liberal supply (such as $2\frac{1}{2}$ ounces to the imperial quart measure of water) of freshly roasted and finely ground coffee into the coffee-pot; pour over it *cold* water in quantity rather more than half the required quantity of liquid coffee, place this on the fire, and the moment it boils remove it: it should be allowed to subside for a few seconds, and then be poured off as clear as it will run. The remaining half of the water at a boiling heat is next to be poured on the grounds; the vessel is to be placed on the fire and kept boiling for three minutes: this will extract the bitterness. After subsiding for a few moments, the clear part is to be poured off and mixed with the former liquor. The mixed liquor will be quite hot enough, and will contain all the desirable qualities of coffee in perfection.

After the above directions it is not necessary to notice the numerous forms of coffee-pot which are brought before the public with so much pretension. The *percolator*, introduced by Count Rumford, has been repeated under a great variety of forms: the objections to it are, that it does not exhaust the ground coffee of its virtues, and that the liquor requires so long a time to percolate, that it is too much cooled before it passes through.

The use of a small quantity of carbonate of soda is said to improve coffee. Professor Pleischl states, that the well-water of Prague is admitted by all to be better adapted to the making of coffee than the river-water of that place. On examining the well-water he found it to contain a small portion of carbonate of soda. He therefore recommends the addition of 43 grains of the pure carbonate to every pound of roasted coffee: this, he says, will improve the flavour, and increase its therapeutic effects by neutralising the acid contained in the infusion.

Those who use fining materials will find a piece of clean eel or sole skin answer the purpose, or still better, white of egg prepared by pouring the white of a number of eggs into a large flat dish, and exposing this for 12 or 14 hours to heat in front of the fire. As the water evaporates, the albumen forms into a yellow, transparent, hard, shining brittle mass, which scales off at the least touch, a test that it is properly done. This may be kept in a bottle for a great length of time, and when wanted, a small piece of about the weight of a sixpence is sufficient to clear 3 ounces of coffee. It must be thrown into that half of the water which is to be boiled, and when the two portions are afterwards mixed, the coffee will become quite transparent in a minute or two.

The addition of a single tea-spoonful of port wine improves the flavour of coffee. It is common on the continent to use ardent spirits with coffee; this however is not coffee drinking, but dram drinking.

The duty on coffee, by the new tariff, was fixed at 6*d.* per lb. from foreign countries, and 4*d.* per lb. from British possessions. This reduction of duty has led to a reduction in the prices of coffee of from 15 to 22 per cent.; and yet, while the increased consumption of sugar, and of every other taxed article, has during the same period furnished conclusive evidence of the soundness of the doctrine, that every judicious reduction of taxes must eventually more than compensate the Exchequer for the temporary sacrifice of revenue, coffee alone has presented the anomalous and exceptional instance of a commodity whose consumption has not only not increased, but has actually decreased as its price has diminished. In 1846, there were entered for home consumption 36,793,061 lbs. of coffee, and in 1849 only 34,431,071 lbs. The revenue from coffee has of course also fallen off from 756,838*l.* in 1846, to 746,436*l.* in 1847; from 710,270*l.* in 1848, to 643,218*l.* in 1849; and for the 11 months, ending 5th December, 1850, to about 550,000*l.* This falling off cannot be attributed to a diminished demand for the article called or mis-named coffee, but to an extensive system of adulteration. For some time, chicory was the chief article used in adulterating coffee; but it is stated that "there are other roots which when kiln-dried, curl up, and assume the same appearance as chicory root; the parsnip, the white-carrot, the beet-root, the radish, and any such. Many of the growers of chicory have hit upon the plan of adulterating it, by the addition of these roots, to the extent of 25 and frequently 50 per cent." Nor are torrefied vegetables the only fraudulent substitutes for coffee, nor the most deleterious. It is stated by some of the London memorialists on this subject, that the substances most largely used are roasted acorns, peas, beans, red-pottery, earth, sand, mahogany saw-dust, colouring matter, and finings.

COFFER-DAM. See BRIDGE.

COG. See WHEEL.

COHESION, (Lat. *cohærere*, to hold together,) the force by which particles of matter form collective masses, requiring the application of force to separate them. The common notion of matter in the solid and liquid states is, that the particles of which they are composed are in absolute contact. This view, however, is quite inconsistent with the well-known property of matter, to expand by heat, and to contract by cold: it is also inconsistent with other facts, such as the peculiar manner in which liquids

mingle; water and sulphuric acid, or water and alcohol, for example, when mingled together, produce an apparent penetrability of matter; a pint of water and a pint of sulphuric acid producing considerably less than two pints of the mixture. We may also notice the intimate manner in which liquids penetrate into the interior of solids. The particles of the stone filter allow water to pass through, which would not be the case if those particles were contiguous or in contact. Hence the particles must be separated by interstitial spaces, by some force which tends to remove them further apart; while another force acting in an opposite direction, tends to unite them or to bring them closer together. This latter force is called *cohesion*, and the former is supposed to be *heat*.

The nature of this attractive force, or cohesion, is not known. There are similar forces in nature, such, for example, as are exhibited by vitreous and resinous substances, which acquire by simple friction the property of attracting light bodies; so also, the lodestone attracts iron, and is attracted by it. The celestial bodies gravitate towards each other with a force which is directly as their mass, and inversely as the squares of their distances. The forms of these bodies, as well as the form of our earth, are such as masses of matter would naturally take when impressed with a rotatory movement, supposing their particles in the first instance to be free to move according to the above law. The attraction is less apparent, but not less real, when exerted between the particles of solid and those of liquid bodies, into which they are plunged. Examples of this were given under CAPILLARY ATTRACTION. The wonderful changes which are brought about in chemistry, result from the operation of forces acting only at very small distances, modified however by the nature of the particles, or by their form, or by both together. The infinite number of particles which react on each other, and the variety of circumstances which modify their properties, render this subject very complex.

The great antagonist of cohesion is *heat*. A bar of metal exposed to its influence expands, that is, the particles are separated from each other to greater distances; by continuing the application of heat, the force of cohesion may be so far weakened, that the particles will glide over each other and form a liquid; that this is a forced state, is evident from the fact that by withdrawing a considerable portion of the heat, the particles approach closer together, until the solid state is formed; a further reduction of temperature brings them still closer together, and causes the solid to contract, or in other words, the attractive force of cohesion prevails over the repulsive force of heat.

But this separation of particles can be carried much further in some bodies than in others: in water, for example, a range of temperature from 32° to 212°, which would have very little effect on a bar of metal, is sufficient to render water solid at the lower temperature, liquid at intermediate temperatures, and vaporiform at the higher temperature. Now, the water in the state of vapour occupies a space 1,600 times greater than in the liquid state: nevertheless, it has not changed its nature: its particles are separated to so great a distance from each other as to be invisible; but we have only to lower the temperature, and they will reunite into drops and return to the state of liquid. On continuing to lower the temperature, we arrive at a point when water not only ceases to contract by cold, but apparently, in opposition to the universal law, expands. This point, at which water is in its state of greatest condensation by cold, is 39.45° Fahr.: below this, any reduction of temperature down to 32° produces expansion, during which the particles probably arrange themselves into that state or condition necessary to the freezing or crystallization of water. At 32° the fluid water becomes solid ice, and a still further and sudden expansion takes place the moment the water becomes solid.

But the state of vapour is not the last term of this remarkable series of changes. If we pass vapour of alcohol through a red-hot porcelain tube, the constituents of the alcohol separate: solid carbon is deposited, and the other constituents are evolved in the aëriform state, in the form of permanent gases, which cannot be reduced to the liquid form by any amount of cold which we can command. Now, in this case, as well as in the case of water in the vaporiform state, the cohesion of the particles is not only entirely overcome; not only is their mutual attraction destroyed; but a force of an entirely opposite nature is generated; the particles repel each other with an intensity depending on the temperature. It is this repulsive force which leads to the bursting of steam-boilers, and which gives elasticity to air-cushions. Only there is this difference, that the vapour of water and other liquids can by simple reduction of temperature be condensed again into liquids; whereas gaseous bodies, such as oxygen, hydrogen, and nitrogen, have never been condensed into liquids by the application of intense cold and pressure. Hence these bodies are called *permanently elastic*,—a term which must not be taken too strictly, because Dr. Faraday, many years ago, condensed to the liquid state eight gases, which had previously been regarded as permanently elastic; and more recently he has not only liquefied, but solidified several others. All the gases thus condensed, except chlorine, are compounds. [See CARBONIC ACID.]

These facts also tend to throw some ambiguity into the term, "the natural state of bodies;" for the solid state is as natural to water as the liquid, provided the temperature be sufficiently low; and the vaporiform state is as natural as the solid and the liquid, provided the temperature be sufficiently high.

By hammering, or by other means of compression, some solid bodies can be made more *dense*, or, in other words, a larger amount of matter, or a greater number of particles, can be crowded into a given space. But there is, doubtless, a limit to this,—a point at which the cohesive force ceases and the repulsive force begins. It has also been suggested by Mossotti

that there might be an intermediate distance, at which the particles neither attract nor repel one another, but remain balanced in that stable equilibrium which they appear to maintain in solid and liquid substances. As the particles are not in actual contact, Mossotti supposes each particle to be surrounded by an atmosphere of electric fluid; that the atoms of this fluid repel one another; that the molecules of matter repel one another, but with less intensity; and that there is a mutual attraction between the particles of matter and the atoms of the fluid. He also assumes those forces which are known to exist, to vary inversely as squares of the distance. From the adjustment of these three forces, the following results have been obtained:[1]—"When the material molecules of a body are inappreciably near to one another, they mutually repel each other with a force which diminishes rapidly as the infinitely small distance between the material molecules augments, and at last vanishes. When the molecules are still further apart, the force becomes attractive. At that particular point where the change takes place, the forces of repulsion and attraction balance each other, so that the molecules of a body are neither disposed to approach nor recede, but remain in equilibrio. If we try to press them nearer, the repulsive force resists the attempt; and if we endeavour to break the body, so as to tear the particles asunder, the attractive force predominates, and keeps them together. This is what constitutes the *cohesive force*, or *force of aggregation*, by which the molecules of all substances are united. The limits of the distance at which the negative action becomes positive, vary according to the temperature and nature of the molecules, and determine whether the body which they form be solid, liquid, or aëriform. Beyond this neutral point, the attractive force increases as the distance between the molecules augments, till it attains a maximum; when the particles are more apart, it diminishes; and as soon as they are separated by finite or sensible distances, it varies directly as their mass, and inversely as the squares of the distance, which is precisely the law of universal gravitation. In aëriform fluids, the particles of matter are more remote from each other than in liquids and solids; but the pressure may be so great as to reduce an aëriform fluid to a liquid, and a liquid to a solid, as in Faraday's experiments.

"If the particles approach sufficiently near to produce equilibrium between the attractive and repulsive forces, but not near enough to admit of any influence from their form, perfect mobility will exist among them, resulting from the similarity of their attractions, and they will offer great resistance when compressed; properties which characterise liquids, in which the repulsive principle is greater than in the gases. When the distance between the particles is still less, solids are formed; but the nature of their structure will vary, because at such small distances the power of the mutual attraction of the particles will depend upon their form, and will be modified by the sides they present to one another during their aggregation. Besides these three conditions of matter, there is an infinite variety of others, corresponding to the various limits at which the two contending forces are balanced, which may be observed in the fusion of metals, and other substances, passing from hardness to toughness, viscidity, and through all the other stages to perfect fluidity, and even to vapour.

"The effort required to break a substance is a measure of the cohesive force exerted by its particles, which is as variable as the intensity of the repulsive principle. In stone, iron, steel, and all brittle and hard bodies, the cohesion of the particles is powerful, but of small extent. In elastic substances, on the contrary, its action is weak, but more extensive. Since all bodies expand by heat, the cohesive force is weakened by an increase of temperature.

"Every particle of matter, whether it forms a constituent part of a solid, liquid, or aëriform fluid, is subject to the law of gravitation. The weight of the atmosphere, of gases and vapour, shows that they consist of gravitating particles. In liquids the cohesive force is not sufficiently powerful to resist the action of gravitation. Therefore, although their component particles still maintain their connexion, the liquid is scattered by their weight, unless when it is confined in a vessel, or has already descended to the lowest point possible, and assumed a level surface from the mobility of its particles and the influence of the gravitating force, as in the ocean, or a lake. Solids would also fall to pieces by the weight of their particles, if the force of cohesion were not powerful enough to resist the efforts of gravitation."

As examples of the force of cohesion we may mention the spherical form of rain-drops; the difficulty of detaching a plate of glass from the surface of water,—the cohesion of the upper layer of water in contact with the glass to the layer immediately beneath it resisting the separation; the perfect manner in which two freshly-cut surfaces of caoutchouc unite on being pressed together; the force, often amounting to a considerable weight, required to separate two smooth plates of brass or glass which have been firmly pressed together with a screw-like motion; these and similar examples of the force of cohesion are independent of atmospheric pressure: the plates of metal will cohere and support the same weight attached to the lower plate when the plates are suspended by the upper one in the exhausted receiver of an air-pump. A remarkable instance of cohesion is mentioned by M. Pouillet:[2]—in plate-glass manufactories after the large plates have been finally polished, they are carefully wiped and set up on edge, resting against each other a little inclined, something like books on a bookshelf. In the course of time, and in this position, the surfaces cohere with a greater or less degree of force, and in some cases it was found impossible to separate the plates without breaking them; in this way three or four plates have become so intimately incorporated, that they could be worked as one plate, cut with the diamond, and ground into shape. Some

(1) The statement of these results has been abridged from Mrs. Somerville's "Connexion of the Physical Sciences."

(2) "Elémens de Physique Expérimentale." Liv. VI.

specimens of glass which had thus grown together at the ordinary temperature, and by contact only, appeared as if they had been fused together: a very powerful mechanical force was required to make the uniting surfaces slide upon each other, and when they were apparently separated it was found that one surface had torn off large flakes of glass from the other.

Some remarkable effects of the cohesion of liquids have been observed by M. F. Donny,[1] who found that a syphon gauge constructed by him with sulphuric acid, (perfectly free from air,) for the purpose of testing the air-pump vacuum, was useless; the acid remaining stationary, it being sustained by its adhesion to the tube, and the cohesion between its own particles. By means of these forces alone a column of sulphuric acid (free from air) was sustained 4 feet in height even in a perfect vacuum, although the apparatus was repeatedly agitated. With distilled water free from air the same phenomenon was observed; and by a series of comparative experiments the author is led to believe that cohesion alone can sustain a column of water over 33 feet. It is the absence of air alone that allows the particles of liquids to approach each other more closely and exercise more powerfully their cohesion, which, when air is present, interferes but slightly with the changes that liquids undergo; as, for instance, ebullition, which happens at about the temperature at which their vapours enter into equilibrium with the atmospheric pressure. But if water is as free from air as it is possible to make it, it can be heated to the temperature of 275° Fahr. without manifesting the slightest traces of ebullition, and that even in a vacuum. This remarkable fact has been proved by experiment, the instrument used for it being a kind of water hammer, so arranged that the vapour in the upper part could not be heated, and thereby exercise a pressure on the water,—which was heated to 275° without the cohesion of the particles giving way; showing that this force was superior to the pressure of 3 atmospheres, as under ordinary circumstances water, heated to 275°, furnishes a vapour equal to that pressure. But if the water heated to this high temperature be divided in any way, steam is instantly disengaged and with great violence, the temperature at the same time falling. In this way those sudden bursts of vapour which are often so annoying during the evaporation of liquids, are explained. At the first part of the ebullition, while air is present, the vapour is uniformly produced, the temperature of the water and of the vapour being the same; but the air once gone, the cohesion of the liquid interferes in the process; this induced the author to try what effect a current of air passing through the liquid would have in preventing these explosions, which resulted in perfect success. M. Donny thinks that the cause of certain explosions of boilers may be deduced from these facts, and proposes as a means of preventing them, to throw in at the bottom of the boiler a small stream of air. These experiments have an important bearing upon the point of ebullition of liquids.

(1) "Annales de Chimie," February, 1846; quoted in Silliman's American Journal of Science.

Some remarkable experiments by Professor Henry, on the cohesion of water, are recorded in the Proceedings of the American Philosophical Society, for April, 1844. The professor attempted to measure the cohesion of water by weighing the quantity of water which adhered to a soap-bubble just before it burst, and determining the thickness of the film by observing the colour it exhibited in comparison with Newton's scale of thin plates. Although experiments of this kind could only furnish approximate results, yet they showed that the molecular attraction of water for water, instead of being only about 53 grains to the square inch, according to the theory of capillarity of Young and Poisson, is really several hundred pounds, and is probably equal to that of the attraction of ice for ice. The cohesion of the particles of water was further illustrated by blowing a bubble at one extremity of a bent tube: on ceasing to blow, and removing the thumb from the other end of the tube, such was the contractile force of the bubble, that it sent a current of air out of the open end, sufficient in force to blow out a candle.

COINING. The art of making the current coin of the realm is one which has participated in a most striking manner in the modern improvements which have been made in self-acting machinery. A visit to the Royal Mint is calculated to excite a high feeling of admiration on account of the perfect arrangements by which vast quantities of the precious metals pass through various processes, under the superintendence of numerous workmen, and resulting in the production of very beautiful coins, or of sets of coins, in which all the individuals of the same name are identical in shape, appearance, and weight, and all this with scarcely any appreciable loss.

Previous to the reign of Charles II. money was made by forging or hammering slips of gold and silver to the proper thickness, then cutting squares from these slips, and afterwards rounding them and adjusting them to the weight of the money to be made. These blank pieces were then placed between two dies containing the design of the coin, and the upper one was struck with a hammer. One of these old dies, an upper one, was found some years ago in Westminster Abbey, and was sent to the Mint, where it is now preserved; but the face of the die is too much corroded to be legible. This method of coining is exceedingly imperfect, from the difficulty of placing the two dies exactly over each other, and the uncertainty of the blow in producing a perfect impression. The coining-mill or press seems to have been introduced into England in the reign of Elizabeth; but its use was abandoned in the course of a few years, and the hammer coinage resumed. About the year 1623, Briot, a French artist, not being able to get the French Government to adopt coining machinery of his contrivance, came to England, where he was favourably received. His press was erected in the Royal Mint under his direction, and he was appointed chief engraver. During about forty years the hammer was occasionally resumed, but by 1662, the mill and screw were permanently established in the

Royal Mint. From this time British coins improved in form and impression until their present state of perfection was attained by the erection of Boulton's machinery.

As our business is to describe the machinery of the Mint, we must pass over the curious and interesting history of its establishment, merely stating the names of the officers, and tracing very briefly the progress of a quantity of gold or silver through the different processes.

The establishment of the Mint consists of the Deputy Master and Worker, who receives the bullion of gold and silver which is brought to the Mint for the purpose of being coined.

The King's Assayer assays the gold and silver as to its quantity and fineness.

The Comptroller keeps a record of the bullion brought in as declared by the weigher and teller, the fineness as reported by the assayer, the value, the owner's name, and the date.

The names of the following officers will sufficiently explain their duties:—

The Superintendent of Machinery, and Clerk of the Irons.

The King's Clerk, and Clerk of the Papers.

The Master's Assayer.

The Master's First Clerk and Melter.

The Provost and Company of Moneyers.

The Chief Engraver.

The Weigher and Teller.

The Surveyor of Meltings.

The Surveyor of the Money Presses.

The Probationer Assayer.

The Master's Second Clerk.

The Assistant Engraver.

The Mint or Bullion Porter.

The Warden of the Mint.

The Stamper of Money Weights.

The Solicitor of the Mint.

The Bank of England is the usual importer of gold bullion. When the Bank sends to the Mint a parcel of gold for coinage, twelve ingots are deposited with the Master's Assay Master, and under the key of the deputy master, where they remain until the assay master has made an assay of every ingot separately. When ready for delivery, the assayer makes his report to the master and worker or to his deputy, and the importers are required to attend in the Mint Office of Receipt, where the assay-reports are read over by the weigher and teller. They are recorded according to numbers in the journals of the master comptroller, and master's first clerk. A mint-bill is given to the importer, stating the weights, fineness, and value of the several ingots. When the bullion is delivered in the state of coin, this bill is received back by the deputy master and worker. The first clerk and melter is then required to pot the gold for melting, and the same is recorded in the pot-book. The surveyor of meltings attends, and sees that they are properly melted and cast into bars. Should the gold be above or below the standard, or, as it is called, when the *betterness* and the *worseness* of the ingots do not balance each other, the alloy of copper is added for the betterness, and of fine gold for the worseness, in order to produce the proper standard of the coin.

The gold is melted in pots of black-lead. Each pot is first placed in a furnace, which is 14 inches square, and 20 inches deep from the grate. The pot is placed on a stand usually cut from the bottom of an old pot, and is about 1 in. or $1\frac{1}{2}$ in. thick. This is covered with coke-dust to make the pot part easily. The mouth of the pot is also furnished with a muffle made by cutting across an old pot, and placing the wide end on the mouth. This muffle is also covered with the other half of the old pot, and its object is to give additional depth to the pot, and to allow the fuel to be piled up higher around it, so as to equalize the heat, and so preserve a uniform mixture of alloy and fine gold. By removing the top, the process of melting can be inspected. The furnace is lighted by placing ignited charcoal round the pot; coke is then added, the furnace door being kept open, and the damper closed, so as to heat the pot gradually. When it is at a bright red-heat, the gold is charged in, in quantity varying from 90 to 105 lbs. troy. It is melted in about an hour, and is then well stirred with a rod of black-lead heated to redness. The pot is then lifted to the top of the furnace by means of tongs, which encircle it, and the gold is poured into two moulds, which produce two bars 10 inches long, 7 inches wide, and 1 inch thick. The pot is then returned to the furnace, where it receives a fresh charge, and this operation is repeated with the same pot eight or ten times a-day.

A sample cut from each of the bars is put up in paper, and marked by the surveyor of the meltings with the number of ingots in the pot, the gross weight, and the quantity of alloy or of fine gold. The bars are then weighed and placed in a stronghold until the king's assay master reports it to be of standard quality. If of standard quality, he sends an order for its delivery to the moneyers for the purpose of coining it. The bars are then conveyed to the office of receipt and delivery, and weighed by the weigher and teller in the presence of one of the check officers, one of the moneyers, and the melter; the moneyer giving a receipt to the melter.

The silver bullion imported into the Mint passes through the same preliminary stages. The weight of silver ingots is from 50 to 60 lbs. Troy each; these are numbered, assayed, weighed, and potted for melting. Silver is reported in ounces and pennyweights, and the standard is computed to that of 11 oz. 2 dwts. fine silver, and 18 dwts. alloy. When melted, 3 samples are taken, from the first, the middle, and the last poured bar of each pot. The metal is melted in air-furnaces, F, Fig. 599, of brick-work cased with cast-iron plates put together with screws. Each furnace is circular within, 30 inches deep, and 21 in diameter, and its mouth is closed by a cover *c*, attached by a single screw-pin, and moving easily upon rollers, by drawing the handle *h* on one side. The grate is of cast-iron bars, and within it is a stand of cast-iron with a concave surface, which is covered with

charcoal dust, 1 inch thick, for holding the melting-pot and protecting it from the heat. The pot P, which is of cast-iron, is capable of melting from 400 to 450 lbs. at one charge. The mouth of the pot is furnished with a muffle or ring of cast-iron to increase its depth, and this is covered with an iron plate to prevent the fuel from falling into the pot, and also to protect the metal from the action of the air. Coke is the fuel, and the heat is regulated by a nicely fitting damper to the flue *f* of each furnace. The furnace doors *c* have small holes in them stopped with plugs of cast-iron, on taking out one of which the contents of the furnace can be inspected. The pot is raised to a bright red-heat in about two hours, and before charging, it is examined to see that it is not cracked; this is done by putting a cold iron tool into the middle of the pot, which immediately

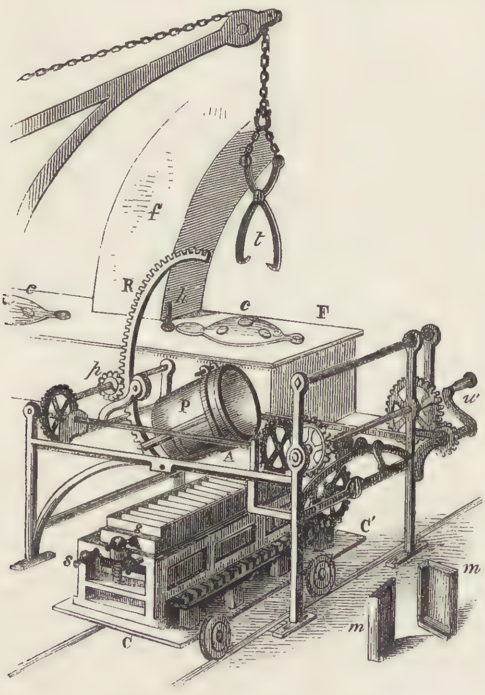


Fig. 599. CASTING SILVER INGOTS.

renders any crack visible. A small quantity of coarsely grained charcoal powder is put in with the silver, and this coats the surface of the pot and prevents the silver from adhering to it. When the silver is at the fusing point, a layer of half an inch of charcoal is added to protect it from the action of the air, which would refine the silver by destroying much of the alloy. It is well stirred up with an iron stirrer to make the whole mass of the uniform standard quality. The pot P is then lifted out by means of the tongs *t* of a crane, and being wound up to the required height, it is swung round into the pouring machine into a frame holding an axis A, to which is fixed a cradle which receives the pot. This cradle is jointed so as to open and shut, and from its principal bars proceeds an arched rack R, which is engaged by a pinion *p*, and can be elevated so as to pour the metal from the lip or spout in the edge of the pot. The axis is turned by a winch. The frame of the pouring machine has an open space beneath for the reception of the carriage C, containing the ingot moulds. These are of cast-iron, each is made in two parts, shown at *m m′*, which being put together form a complete mould, the upper edge of which is a little enlarged to facilitate the pouring of the metal. Before the moulds are used, they are heated in a hot iron closet and rubbed on the interior with linseed oil. A row of moulds is screwed up closely in the carriage by means of two screws *s*; the moulds rest on a plate which is suspended by screws at each end, and can thus be raised or lowered. The carriage is supported on 4 wheels running on a railway. To the bottom plate is fixed a rack *r*, which acts on a cog-wheel which is turned by a pinion with a handle; by this means the carriage is moved along the railway, and any one of the moulds can be brought under the spout of the melting-pot, and by turning another handle the pot can be inclined so as to fill the mould. There are 8 of these furnaces at the Mint, each of which being worked three times daily, and each pot containing on an average 420 lbs., the total melting amounts to 10,080 lbs. One crane is situated in the centre of 4 furnaces; there are 4 men to each of the 4 furnaces, and the whole melting is finished in about 10 hours.

If the bars of silver are of the approved standard, they are delivered to the moneyers, who, as in the case of gold, always deliver weight for weight; that is, the coin and the scissel, or the portion left after the circular pieces have been cut out. The silver bars go through the operations of flatting, rolling, or laminating in the rolling mill; but before being put through the rollers, the bars are heated to redness to facilitate the rolling. The gold bars are rolled cold, and a bar of gold an inch thick can be reduced to the thickness of a half-sovereign without being annealed. The rollers are mounted in a cast-iron frame; the upper roller is supported in brasses which fit very accurately in grooves in the standards, and are made to rise and fall therein; these are regulated by large screws, by turning which the space between the rollers is adjusted. The thickness of the plates reduced by the operation of the rollers is ascertained by a gauge, consisting of two steel rulers fixed together at one end, and forming an opening which gradually diminishes; the sides of this gauge are divided, and the edge of the plate being applied to the opening between the rules, the division shows the distance it will go into the opening before it fits tight, and the thickness is ascertained by the number of divisions.

The plates of metal being rolled to the proper thickness, are cut into slips of a convenient width for cutting out the blanks or circular pieces which form the coins; the width of the strip is generally equal to that of two coins. These strips are cut out by means of an ingenious circular shears, Fig. 600, consisting of a strong frame F, in which

two cog-wheels $w\,w$, engage each other, and on the end of the axis of each is a circular cutter, $c\,c'$. The edges of these cutters are of hard steel, turned truly circular; the edges also are made

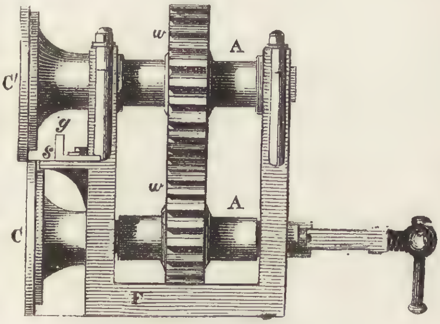


Fig. 600. CIRCULAR SHEARS.

very true and square, they are in close contact laterally and overlap a little. It is obvious that if these discs be made to turn round, and the edge of a plate of metal be presented to them, it will be cut just as with a pair of shears: *s* is a narrow shelf on which the plate is supported when it is pushed forward to be cut, and *g* is a guide fixed on the shelf. The edge of the plate of metal is applied against this guide, while it is moved forward by the cutter. The guide is movable, and the distance which it stands back from the cutting edges, determines the breadth of the slip of metal to be cut off.

Before the strips are cut into blanks, they are reduced to the right thickness by means of finishing rollers, the distance between which is nicely adjusted by making the brass bearings of the lower roller rest on wedges which fit into cross mortises through the standards. By forcing the wedges further in, the brasses of the lower roller are moved nearer to the upper roller. There is of course a wedge on each side. The two are connected together, and moved by a delicate screw adjustment.

The same object is accomplished more successfully by Barton's machine, in which the slips are drawn between dies by an operation somewhat similar to that of wire-drawing. In order that the ends of the slips may enter the dies, they are thinned by means of an ingenious machine consisting of a pair of small rollers, the lower one of which has 3 flat sides upon it. As the rollers turn round, the cylindrical parts take the metal between them, and roll it thinner, while one of the flat sides coming up releases it immediately.

The dies through which the slips are drawn are two cylinders of steel very hard and true. These are fitted into two sliders contained in a box, and are

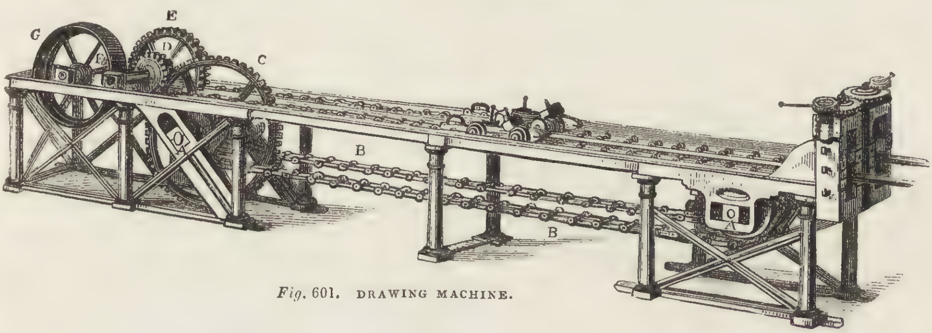


Fig. 601. DRAWING MACHINE.

held fast by clamp pieces screwed against them. The dies fit accurately into their beds, and being prevented from turning round, they present only a small portion of their circumference against the slip of metal. The distance between the two dies is accurately adjusted by means of adjusting-screws fixed in the sliders. The box of dies is fixed at one end of a long frame, Fig. 601, which supports two axes, one at each end, carrying wheels for the reception of endless chains, which move along a sort of trough or railway formed on the top of the frame. The chain is moved by a cog-wheel fixed on the axis most remote from the box of dies. The slip of metal is drawn through the dies by means of a pair of tongs, which run upon wheels over the endless chain and are set in motion thereby. The axle of the wheels acting between the inclined parts of the tails of the tongs tends to throw them asunder, while at the same time the jaws bite with great force, the links drawing the tongs along with the chain. In using this machine, the man takes the tongs by the handle when they are disconnected from the chain, and pushes them forwards towards the box of dies. The tongs run freely on wheels, and the jaws open when moved in that direction. The jaws enter a recess in the box of dies, and another man takes the slip and introduces the thinned end between the dies and also between the open jaws of the tongs. The man who is holding the tongs takes the handle at the back of the tongs, and holds it fast, while with the other hand he draws the handle at the end of the links away from the tongs, the effect of which is to close the jaws of the tongs on the slip between them. He then depresses the handle, and the hook at the end of the links is caught by the first cross pin of the chain which comes beneath them. This puts the tongs in motion; but the first action is to close the jaws with great force upon the slip. The tongs then move with the chain, and draw the slips of metal through the dies, which operate on the thicker parts of the slip with greater effect than on the thin parts, thereby reducing the whole to an equable thickness. When the whole

length is drawn through, the strain on the tongs is released, and the weight, lifting up the hook at the other end of the links, is ready to be advanced again to the dies to draw another bar. In the frame, Fig. 601, there are two pairs of dies, the same wheel serving for both. The slips are thus made more equable than when finished by the adjusting rollers. When the circular pieces, punched out from the slips of metal prepared by the drawing machine, are *pounded* and weighed, that is, the number of pieces in a pound troy counted out, the variation from the standard either way, whether for sovereigns or half-sovereigns, seldom exceeds 3 grains troy. With the adjusting-rollers it was reckoned good work when the variation was under 6 grains troy.

It was formerly the practice at the Mint to cast the bars very thin, so that much of this rolling and drawing was dispensed with. It was found, however, that thin bars were subject to little bubbles, in consequence of the air entering in pouring, so that when the bars were elongated by rolling, they became hollow and defective, and the pieces stamped from them were *dumb*, giving only a dull sound on ringing: this defect was got rid of by increasing the thickness of the castings, and reducing the slips by rolling and drawing.

The plates of metal thus prepared are divided into four parts, and then cut out into blanks, or circular

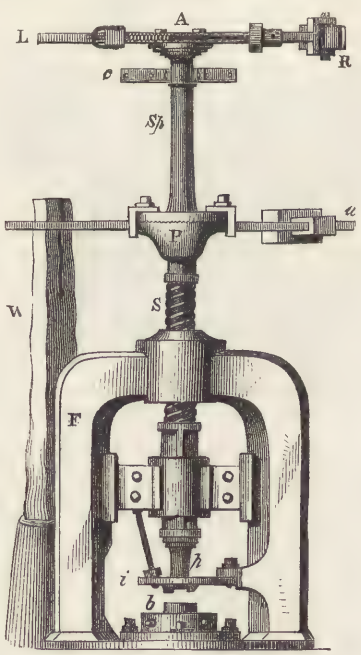


Fig. 602. CUTTING-OUT PRESS.

pieces, nearly of the size of the intended coin. The cutting-out press, Fig. 602, is a beautiful contrivance, invented by Boulton, of Soho. It consists of a cast-iron frame, F, on a stone basement: a screw, S, fitted through the top of the frame, acts on a slider or roller, R, moving up and down in the frame. At the lower end of the slider is a steel punch, *p*, equal in diameter to that of the pieces to be cut out, and exactly under this is a steel die *b*, with a hole in it exactly fitting the steel punch. The punch passes through a piece of iron *i*, fixed a little above the die, the object of which is to hold down the piece of metal when the punch rises, and thus prevent the piece sticking to the punch. To the upper part of the screw is attached a piece P, and an arm projecting from it carries a weight, *w*, which gives the momentum required for punching out the piece. In the line of the screw is a spindle, *Sp*, supported in a collar at the top, above which is a lever, and at one extremity of this lever a roller, R, is fixed: this roller is acted upon by the projecting teeth which are fixed in the rim of a large wheel, moving in a *horizontal* plane.

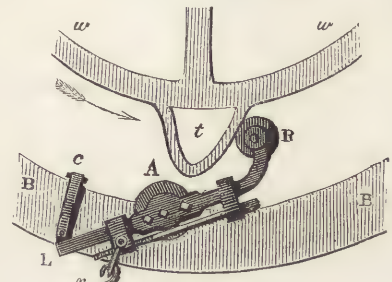


Fig. 603.

Fig. 603, *w w'*, is a portion of the rim of this horizontal wheel: *t* is one of the teeth, or projecting cogs, which, when the wheel turns in the direction of the arrows, takes the roller R, Fig. 602, and turns the lever R A L round in that direction, whereby the screw is wound up, and the punch is raised out of the die. This action also draws a rod, *r*, which is connected by a lever with a joint, and the other end of this rod is connected with a bent lever, from the other arm of which descends a rod with a piston fixed to it, fitting in a close cylinder, so that when the piston is drawn up, a vacuum is produced in the cylinder, and the instant the roller R escapes, or slips off the tooth *t*, the pressure of the atmosphere on the piston causes a reaction of the piston, which draws the joint back, and turns the screw in the direction for making the punch descend into the die, and stamp out a blank from the interposed slip. To stop the machine, a catch connected with a string is attached to a cord, and this to a treadle which is under the command of the attendant's foot, by depressing which, the roller is raised clear of the teeth of the great wheel; and thus one press can be stopped without stopping any of the others. There are twelve of these presses arranged in a circle round the large horizontal wheel, the axis of which is in the centre of a circular room, which is lighted by a skylight in the dome. The air-cylinders for depressing the punches are concealed within hollow pilasters, which ornament the walls of the room, and appear to support the dome. The rod *r*, Fig. 602, is jointed to a piece fitted so as to slide upon the lever R A L, Fig. 603, and is moved by a screw, so as to be fixed at any required distance from the centre, and give greater or less effect to the reaction of the exhausted cylinder. W is a strong

wooden spring, against which the balance-weight strikes, to arrest its motion when it has made the required stroke to punch the plate.

After the blanks are cut out, the residue, called *scissel*, is packed up into journey weights, 15 lbs. of gold, and 60 lbs. of silver: these are carefully weighed by one of the moneyers, and deposited in a stronghold until sent to the melter to be again melted into bars.

The blanks thus cut out are carried to the sizing room, where each individual piece is adjusted to the standard weight; the light pieces are rejected and remelted; the heavy ones are rasped. Each blank is also sounded upon a circular mass of iron, to prevent any dumb or unsound pieces being sent to the other department.

The blanks are very hard, from the compression the metal has undergone: they are softened by being packed in iron cases, 2,804 blanks in each case: this case is put into another iron case, and the space between is filled up with brick-dust, thus effectually excluding air. Five of these cases are placed on an iron truck, and run into the annealing-oven, and raised to a cherry-red heat. 700 blanks make a journey-weight of gold; so that each case contains 4 journey-weights. The journey-weight was formerly a day's work; but at the present time 100 journey-weights are got through in one day.

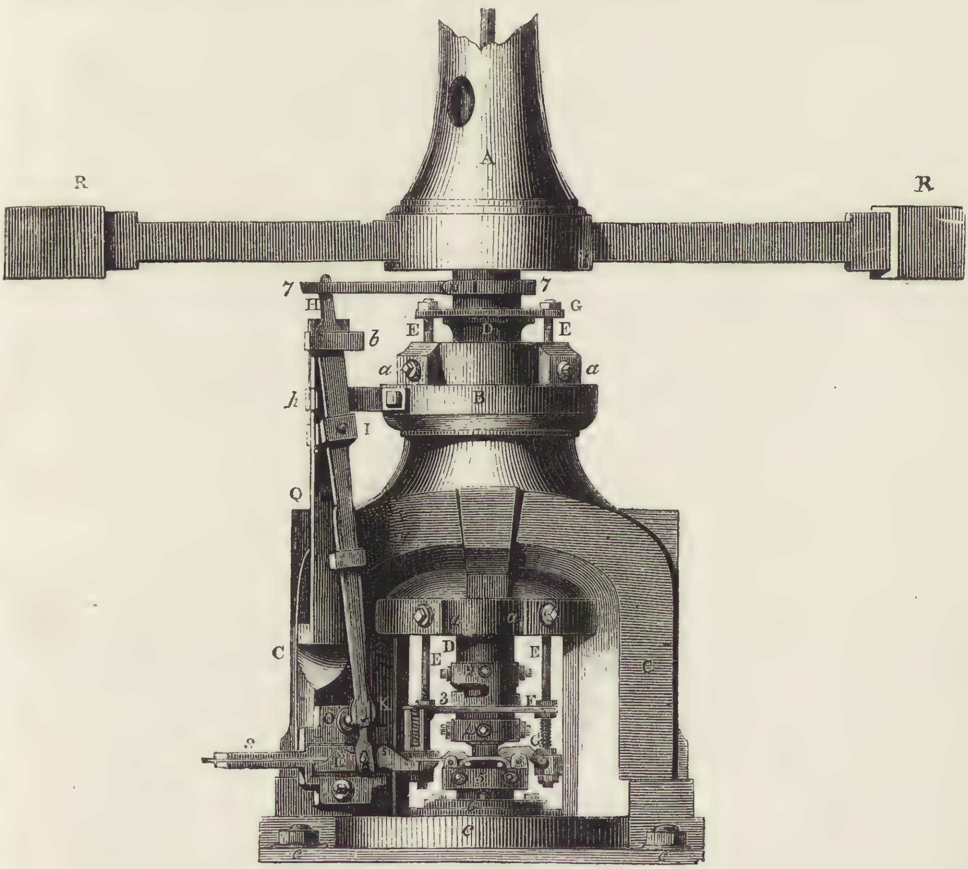


Fig. 604. COINING PRESS.

The annealed blanks are cleaned by boiling in a very dilute solution of sulphuric acid: they are then washed with cold water in a copper colander; then dried in hot sawdust, and, lastly, kept at a gentle heat in a hot cylinder.

At this stage it was formerly the practice to produce the *milling* at the edge, for the purpose of preventing the chipping or filing of the coin, as was the common practice before the introduction of milling or lettering. This is now done at the coining-press, which is next to be described.

Fig. 604 is an elevation of the coining-press for stamping the money. C C B is a strong cast-iron frame, firmly attached to a stone basement by screws, *c c*. The upper part, B, is perforated, to receive the screw, D D. One of the steel dies which strike the coin is fixed to the lower end of this screw by a box, 4, and the other die is fixed in a box, 6, which is fastened down to the base of the press. Heavy balance-weights, R R, are fixed on the top of the screw, which, being turned round, presses the upper die down upon the blank piece of coin, which is placed upon the lower die, and gives the impression; a sufficient force being obtained from the momentum of the loaded arms, R R. The motion is communicated to the screw by a piece A, which ascends to the

ceiling, and is worked by steam-driven machinery situated in the room above. The loaded arms, R R, strike against blocks of wood, whereby they are prevented from moving further than is necessary: if it were not for this precaution, the hard steel dies might come in contact, and be broken. The piece of blank coin is contained within a steel ring or collar while it is being stamped, and this not only preserves its circular figure, but also effects the milling at the edge. This collar rests upon a three-pronged spring, which bears it upwards, and the opening through it fits upon the neck of the lower die, the upper surface of the collar and of the die being in one plane; but the collar admits of being raised up upon the neck, so as to form a recess or cell adapted to receive a piece of money. The collar is thus made to rise and fall by means of the levers, G, which are fitted upon centre-pins, or joints, in a large ring placed on the outside of the box which contains the lower die, and is fixed firmly upon it, as at 5 and 6. These levers, G, are forked at the outer ends, to admit studs at the lower ends of iron rods, E E, which rise up through holes in the solid metal of the press, and are united to a collar, G, fitted on the upper part of the screw, D. When the screw of the press is turned back, and the upper die is raised up, the rods raise the outside ends of the short levers, G, and the inside ends depress the collar: a blank piece of money is then placed, by means of steel fingers, upon the die, and when the screw is turned, to bring down the upper die upon it, to stamp the impression, the levers G are released, and the three-pronged spring lifts up the collar, so as to surround the piece of money while the blow is being struck. The press then immediately returns by its recoil, and the levers, G, force the collar down upon the neck of the die, and leave the piece free. The lower die is fixed in a box, 6, by four screws, which allow it to be precisely adjusted beneath the upper die. The upper die is also firmly attached by four screws in a box, which is fitted in a ring or collar, F, the arms of which are attached to the rods E E by nuts at each end; and this makes the collar F and the box 3 always follow the screw, and keep a close contact with the end of the screw, which enters into a cell in the top of the box 3, but leaves the screw at liberty to turn round independently of the box. 2 is a ring, fastened by its screws to the screw of the press: descending from this ring is a claw, which enters the cavity in the edge of the box 3: this cavity is nearly three times as wide as the claw, so that the screw can turn round a certain distance without turning the box 3; but beyond the limits of this motion, the screw and the die will turn round together. The object of this arrangement is to press the upper die down upon the coin with a twisting motion; but if the die were to rise up with a similar motion, it would abrade and destroy the fine impression: hence, the notch in the ring 3 is so wide as to allow the screw to return and raise the die from immediate contact with the coin before it begins to turn round with the same motion as the screw. 4 is a box, screwed over the box for the upper die in order to keep it firmly in its cell. The great screw of the press is cylindrical at the upper and lower ends, where it is seen at D D, and these ends are accurately fitted in collars bound tight by screws, *a a*; the real screw or worm part is concealed within the solid metal B: its object is to force the die down, the lateral guidance being effected by the collars *a a*. Arrangements are also made for removing every piece of money which is struck, and for feeding the press with a fresh blank piece. H I K is a lever, of which I is the fulcrum: it is supported on a bar, Q, fixed vertically from the cheek of the press, and steadied by a brace *h*. The upper end of the lever is actuated by a sector, 7, fixed upon the screw, D. When the screw turns round, a groove in the sector, being of a spiral curve, moves the end H of the lever to and from the screw; and the lower end, K, of the lever, being longer, moves a considerable distance to and from the centre of the press. *b* is a socket or groove in a piece of metal fixed to the perpendicular bar, Q, in which the upper end of the lever H is guided. The lever K moves a slider, L, which is supported in a socket O, and this slider is directed exactly to the centre of the press, and on the level of the upper surface of the die. The slider is a thin steel plate, made in two pieces united by a joint: the extreme end is made with a circular cavity, so that when the two limbs shut together, they will grasp a piece of money between them, and hold it by the edge; and on separating the limbs, the piece will drop out. On the top of the socket, to the left of 5, is a tube which an attendant keeps filled with blank pieces: this tube is open at the bottom to the slider, and the pieces rest upon it. When the screw of the press is screwed down, the slider draws back to its furthest extent, and the circle formed at the end between its limbs comes exactly beneath the tube. The limbs being open, a blank piece of coin drops down into the circle of the slider; then the screw of the press, in returning, moves the lever H I K and the piece L: this closes the circle upon the blank piece. The slider is pushed forward in its socket, and the piece is carried forward upon the die, and in the act of doing this the slider pushes off the piece last struck. The screw having now arrived at its highest position, begins to descend, and the slider L to return; but just at this point the limbs open, and leave the blank piece upon the die. As the screw of the press descends, the ring before noticed rises up to enclose the piece while it receives the stroke, and the slider P at the same time returns to take another blank from the tube.

The coining-room at the Mint contains eight presses: they are placed in a row on a stone basement, on which very strong oak pillars are erected, reaching to the ceiling. Each press is contained between four such pillars, and iron braces are fixed horizontally from one pillar to another.

The money thus coined is passed through tubes of the diameter of the different species, whereby any defect in size is detected. It is then weighed up in journey-weights for delivery to the importers of the

bullion,—the gold in 15lbs., the silver in 60lbs., Troy. But before delivery to the importers, the money is inspected as to its workmanship, and *pixed.* The process of pixing consists in taking from every journey-weight a pound, promiscuously, and weighing in an accurate balance: if the weight be not satisfactory, the coin is ordered to be melted up and recoined at the expense of the moneyers.[1]

COIR. See COCOA-NUT.

COKE. See CARBON.

COLLIERY. See COAL.

COLOCYNTH, a valuable medicinal agent derived from the bitter cucumber, (*Cucumis colocynthis,*) growing in Turkey, India, &c. The drug consists of the dried pulp, which is white, spongy, and of a nauseous and bitter taste, but without smell. When adulterated, or badly dried, it is of a dirty brown or deep grey colour. This medicine, which is a powerful drastic cathartic, is too violent to be administered alone, but it is given in union with other medicines. Camphor mitigates its violence.

COLOUR. See LIGHT.

COLUMBIUM, a rare metal, found in the Swedish minerals *tantalite* and *yttro-tantalite,* and hence sometimes called TANTALUM. (Ta .185.)

COMB. The materials employed in the manufacture of combs are wood, horn, tortoiseshell, ivory, bone, and metal. The preparatory processes for the two principal materials will be described under HORN and TORTOISESHELL. The materials are first prepared in the form of *plates,* and the methods of cutting the teeth in these have led to some ingenious contrivances. The old method of doing this is by means

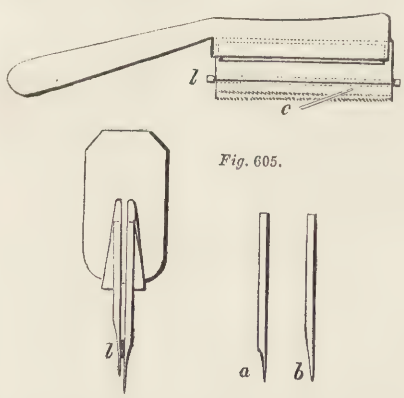


Fig. 605.

of a double saw, called a *stadda,* Fig. 605; it has two blades, so contrived as to give with ease and exactness the intervals between the teeth of combs, from the coarsest to those which have from 40 to 45 teeth in the inch. The blades or plates of the saw are made of thick steel, and are ground away on the edge, as at *a* or *b*, as thin as the notches in the comb, and they have from 10 to 20 points in the inch of slight pitch. [See SAW.] The plates are fixed in two grooves of the stock by means of the *stuffing,* which consists of two long wooden wedges, or folds of brown paper; contact between the plates is prevented by a thin slip of metal, called a *languid, l,* which is of the thickness of the teeth required in the comb *c.* One blade is in advance of the other from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch; at the first process a notch nearly of the full depth is made in the comb, and a second notch is commenced; at the next process the notch in advance is deepened, and a third commenced, and so on consecutively. By this means the teeth can be cut in a regular manner, for the very action of cutting out one tooth scores out a place for the saw for the next adjacent tooth. The openings thus formed are afterwards thinned out and finished by means of thin wedge-shaped files, called *floats.* Some of these files are shown in section in Fig. 606,

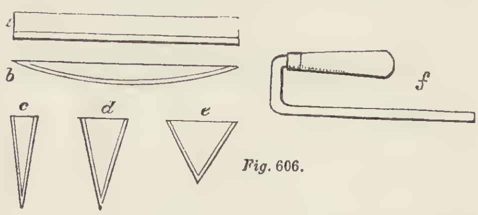


Fig. 606.

the teeth being shown at the points indicated by the double lines; *a* is a *float,* *b* the *graille,* *c* the *found,* *d* the *carlet,* *e* the *topper;* these names are corruptions from the French, and indeed the art of comb-cutting is almost entirely derived from the French. *f* represents what is called a *quannet,* a sort of rasp, with coarse-filed teeth; this is the ordinary flat file of the comb-makers, and in using it the work is mostly placed on the knee as a support.

The introduction of the circular saw led to some improvement in comb-cutting, especially with box-wood or ivory as the material. In a machine invented by Messrs. Pow and Lyne the plate is fixed in a clamp suspended on two pivots parallel with the spindle of the circular saw. By the revolution of the handle, a cam first depresses the ivory on the revolving saw, cuts one notch, and quickly raises it again; the handle in completing its circuit shifts the slide that carries the suspended clamp to the right, by means of a screw and ratchet movement. The teeth are cut with great exactness, and as quickly as the handle can be turned; they vary from about 30 to 80 teeth in the inch, and such is the delicacy of some of the saws that even 100 teeth may be cut in an inch of ivory: the saw runs through a cleft in a small piece of ivory, fixed vertically and radially to the saw, to act as the ordinary stops, and prevent it from being bent or displaced sideways. Two combs are usually placed one over the other and cut at once; occasionally the machine has two saws, and cuts four combs at once.

(1) The reader interested in this subject is referred to the Rev. Rogers Ruding's "Annals of the Coinage of Great Britain and its Dependencies," Third Edition, enlarged, &c. 3 vols. 4to. London. 1840. A great variety of details respecting the Royal Mint, as well as the mints of other countries, will be found in the "Report from the Select Committee of the House of Commons on the Royal Mint," ordered to be printed 30th June, 1837. The mechanical details of the Royal Mint are well described and illustrated by four quarto plates of figures in the Article COINAGE in the "Encyclopædia Britannica," vol. vii., which has assisted us in the preparation of this Article. We have also to express our obligations to Professor Brande, of the Royal Mint, for permission to inspect the processes, and for explanatory details.

In making small side-combs of tortoiseshell the material is economised by the process of *parting,* as it is called. This method is said to be the invention of an artisan named Ricketts, who was led to it by being engaged in the production of ornamented tortoiseshell combs, [see HORN and TORTOISESHELL,] in which the decorated parts were formed by the pressure of cutters. A machine for making parted combs was described by Mr. Rogers in the 49th vol. of the Transactions of the Society of Arts. It has since been remodelled and improved by Mr. Kelly. The following is from Mr. Rogers's description:—*pp*, Fig. 607, is a plate supporting the other parts, and is secured by screws to any suitable bench; *h* is a winch or handle attached to the axle *a*; *u u* are upright pieces, in which the two ends of the axle work, and *u'* is another upright, between which and *u* the crank of the axle is situated. From the bottom plate *p* is a curved projecting piece, on which is hinged the bar *b*; at the end of this bar is a collar *c*, secured by a screw, and connected by means of a link with the cranked part of the axle. When the axle is turned round by means of its winch an alternate up and down motion is given to the bar *b*; *l* is a loop in which the bar works, and which prevents it from swerving to either side; *k* is the cutter, and *t* a piece of tortoiseshell, out of which two parted combs are to be made. The cutters

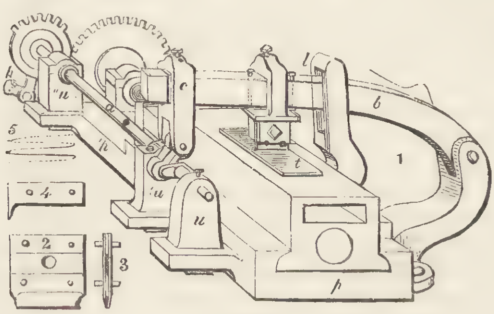


Fig. 607.

Nos. 2 and 3 consist of two sharp blades of steel bent outwards a little at one end, between which are placed wedge-shaped pieces, so as to cause the blades to diverge from each other at the bent end by any required distance; at the other end the blades come nearly but not quite in contact, and this space is filled up by the insertion of the piece No. 4, the sharp tooth of which is so adjusted as to be even with the edge of the blades. When, therefore, this compound cutter is pressed down on the surface of the tortoiseshell, a tooth, such as is shown in No. 5, will be formed. But in order to make a succession of such teeth it is necessary that the piece of tortoiseshell shall have a progressive motion, and that this motion shall be suspended while the cutter is making its blow. These two conditions are effected thus:—in front of the bed on which the tortoiseshell *t* is laid is a rectangular opening, into which a heated bar is put, which, by keeping the tortoiseshell warm, prevents it from splitting by the action of the cutter. The bed slides in a dovetail groove made in the plate *p*, and has a hollow screw in that end of it which is adjacent to the toothed-wheel *w*. From the centre of this wheel projects a solid screw which turns in the hollow one, and consequently moves the bed in one direction or the other, according as the toothed wheel is turned one way or the other. The wheel *w* receives its motion from the wheel *w'*, which being placed on the axle *a*, is turned together with it by the winch *k*. But the wheel *w'* has teeth only on part of its circumference, and therefore, while this is in continued motion, will give an alternation of motion and rest to the wheel *w*, and consequently to the piece of tortoiseshell *t*. While this latter is at rest the cutter makes its stroke, and while the cutter is rising to make another stroke, the piece of tortoiseshell moves through a space equal to the interval between one tooth of the comb and the next. When these actions have been repeated along the whole length of the tortoiseshell, Fig. 608 is produced, which is the full size or nearly

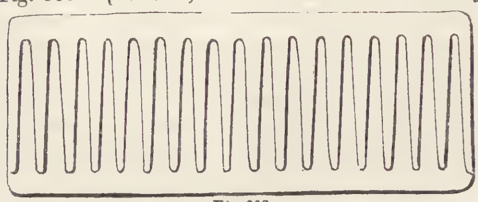


Fig. 608.

so, and a slight pull will part the two pieces, each of which is a separate comb. Such combs are called *parted*, the saw not being used on them, and they are often made of fine stained horn instead of tortoiseshell.

COMBUSTION, a chemical process, in which two substances at least enter into combination, and heat and a new compound are the results. Thus, when antimony in powder, or copper in the form of thin leaf, is presented to chlorine, a combination is instantly effected between these bodies, and a chloride of antimony or of copper is the result, attended at the moment of combination with heat and light. It is usual to reckon five supporters of combustion, viz. oxygen, chlorine, iodine, bromine, and fluorine. Of these, the first is by far the most important. It is one of the constituents of the atmosphere and of water; it enters abundantly into the composition of most bodies in their natural state, and is altogether so important that without it no animal could live, no plant could grow, and, generally speaking, no flame could burn; the other four supporters of combustion, as they are termed, would not support animal or vegetable life.

Before the discovery of oxygen gas combustion was explained by supposing that all combustible bodies contained a certain principle called *phlogiston*, the presence of which enabled bodies to burn. It was further supposed that when a body burned, phlogiston was liberated, and that when a body had lost phlogiston it ceased to be combustible; it was then said to be *dephlogisticated.* The heat and light which accompany combustion were attributed to the rapidity with which phlogiston was evolved.

But according to this hypothesis, a combustible body having undergone the process of combustion

ought to have lost weight, whereas it was found in many cases that the results of combustion were *heavier* than before combustion had taken place. The discovery of oxygen gas proved fatal to the phlogiston theory. Lavoisier burnt phosphorus in a jar of oxygen, and observed that much of the gas disappeared, and that the phosphorus gained in weight; that the increase of the one was in the ratio of the decrease of the other. Iron wire burnt in oxygen gas gave a result equal to the wire employed, plus the weight of the oxygen that had disappeared. Mercury being confined in a vessel of oxygen, and exposed to the temperature of about 600°, the gas combined with the metal, and the resulting oxide being heated to about 900°, was reconverted into oxygen gas and metallic mercury; the quantity of oxygen thus recovered answering precisely to that employed in the first instance to produce the oxidation.

In ordinary cases of combustion the heat evolved does not depend upon the combustible, but upon the quantity of oxygen that enters into combination. Thus, according to Despretz, a pound of oxygen, in combining respectively with hydrogen, charcoal, alcohol, &c., evolved in each case nearly the same amount of heat, each raising 29 lbs. of water from 32° to 212°. A given weight of different combustibles gives the comparative quantities of heat represented by the following figures:—

	lbs. of water.		
1 lb. of pure charcoal raised .	78	from 32°	to 212°.
„ common wood charcoal	75	„	„
„ baked wood	36	„	„
„ wood, holding 20 per cent. of water . .	27	„	„
„ bituminous coal . .	60	„	„
„ turf	25 to 30	„	„
„ alcohol	68	„	„
„ oil, wax	90	„	„
„ ether	80	„	„
„ hydrogen	236	„	„

The products of combustion in oxygen or its compounds form the three great classes of *acids*, *alkalies*, and *oxides*.

COMPASS, an instrument consisting of a magnetic needle or bar, mounted on a fine centre, enclosed within a shallow box or metallic case, and furnished with a plane circular card, denoting the *chief* or *cardinal* points of the horizontal plane about us. The term *compass* is immediately derived from the card which *compasses* or involves as it were the whole plane of the horizon. The compass-needle N S, Fig. 609, is usually a light bar, set edgewise upon an agate centre; sometimes it consists of a thin piece of steel plate tapering from the centre to the extremities,

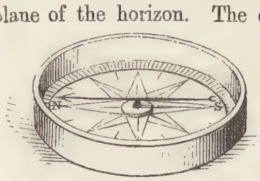


Fig. 609.

and it may be of any dimensions according to the size of the compass required. The compass or card which indicates the various points in the horizon with reference to the direction of the magnetic needle, is either fixed in the case immediately under the needle and separate from it, or it is attached to the needle itself, as in Fig. 611, so as to traverse with it. In the former case it is made of cardboard or metal; in the latter, of some very light substance not liable to warp from heat or moisture, such as a thin plate of talc.

In the magnetic compass, the plane of the horizontal circle is divided into 32 parts by lines supposed to be drawn diametrically through the circle. These, as practically applied to the compass card, are called *points of the compass*, or in nautical language, *rhumbs*. In marking the compass card Fig. 610, the circle is first divided into two semicircles by a diameter N S, which denotes the line of the magnetic meridian; and

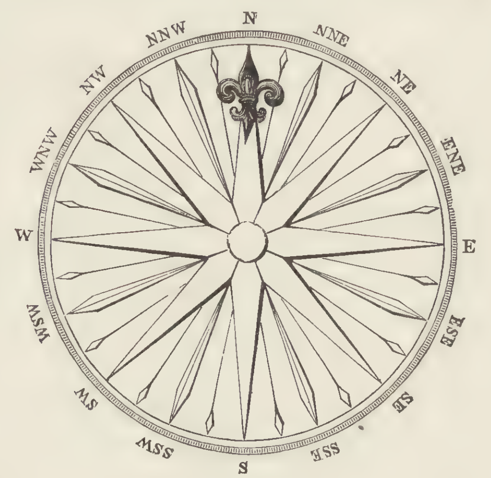


Fig. 610. THE COMPASS CARD.

the north point, as being the most elementary or great point of reference, is usually distinguished by an ornamental arrow or fleur-de-lis. A diameter E W is next drawn at right angles to the other, by which we obtain the east and west line, and thus we have the 4 principal or elementary cardinal points. The quadrants of the circle between these 4 points are further and equally divided by 2 other diameters producing four new rhumbs or points. These are named from their relative position in the compass. The point midway between N and E, for example, being compounded as it were of the two directions, is termed north-east, and is marked N E. That midway between N and W is termed north-west, and marked NW: that between S and W is termed south-west, and marked SW: that between S and E is south-east, and marked SE.

We thus obtain 8 principal points or rhumbs, and by continuing the division by diameters, bisecting the arcs contained by these first 8 points, we obtain an additional 8 points, making in all 16 points: these additional points are named as before from their position in the compass. The point midway between N and NE is termed north-north-east, as being nearer north than east, and is hence marked with two letters N, thus NNE. In a similar way the point between east and north-east is termed east-north-east,

as being nearer the east, and is marked thus, ENE; and so on of the remaining bisected arcs: thus we have the points NNW and WNW for the points between north and west; SSW and WSW for the points between south and west; SSE and ESE for the points between south and east.

By continuing to bisect the arcs included between these points, we again double the number of rhumbs, and obtain 16 additional points, making in all 32 points: these are also named from their position in the compass, with the addition of the word *by*. Thus the point midway between N and NNE is called north by east and is marked N by E; that between N and NNW, north by west, and is marked N by W; the point between NE and NNE is called north-east by north, and is marked NE by N, and so on, leaning for the designation towards the nearest of the four elementary cardinal points. Thus the point midway between E and ENE is termed east by north and is marked E by N. In this way we arrive at 32 rhumbs or divisions of the circle into points, which taken in succession from the first or principal point, north, and carried round the circle in either direction, east or west,—suppose in the east direction, will stand thus:—

N.	E.	S.	W.
N by E.	E by S.	S by W.	W by N.
NNE.	ESE.	SSW.	WNW.
NE by N.	SE by E.	SW by S.	NW by W.
NE.	SE.	SW.	NW.
NE by E.	SE by S.	SW by W.	NW by N.
ENE.	SSE.	WSW.	NNW.
E by N.	S by E	W by S.	N by W.

An enumeration of these successive points from memory is called *boxing the compass*. More minute divisions of the compass card are estimated by what are called *half* and *quarter points*, each point being divided or supposed to be divided into 4 equal parts, so that any small angular quantity between either of the 32 divisions or points just enumerated, as, for example, between N and N by E would be termed, north-a-quarter-east, or north-half-east, or three-quarters-east, as the case may be: we then arrive at north by east, and so of all the other points. Thus north by west, a little to the north or west, would be called north by west a quarter, or half, &c. north, or a quarter, or half, &c. west, as the case may be.

For more refined purposes, the compass is enclosed by a graduated circle, divided in the usual way into 360 degrees, by which the rhumbs are estimated in angular quantities, each rhumb or point being the $\frac{1}{32}$d part of 360°, or $\frac{360°}{32} = 11° \, 15'$: a half-point will be then $5° \, 37' \, 30''$; a quarter-point $2° \, 48' \, 45''$.

When the compass-card is fixed to the box or case in which it is enclosed, and the needle is allowed to traverse over it, we have what is usually termed a *land compass*. It is commonly used by travellers for determining the different points of the horizon, the box being turned so as to bring the north and south points of the card immediately under the north and south poles of the needle. In this case, all the other points, as referred to the magnetic meridian of the particular locality, are correctly placed. The land compass is also occasionally employed in the measurement of angles in surveying instruments. It may be, for general purposes, of any moderate size, from that of a common seal up to the diameter of a foot. The land compass has usually a spring stop under the needle, by which it may be thrown up and retained clear of the point when not in use.

A fixed compass-card, as applied in the land compass, could not be used on ship-board for determining the position of the cardinal points in reference to the magnetic meridian, because the vessel is continually varying its position, and is in continual motion: it becomes therefore requisite to construct the compass-card of some light substance, not liable to warp or to be injured by heat and moisture. This is attached to the needle itself, so as to admit of both card and needle traversing together. If the needle be fixed to the card with the north and south poles immediately under the north and south poles of the compass, then all the points of the card will be correctly placed in reference to the magnetic meridian of the place, in whatever direction the vessel be turned; that is to say, supposing that no disturbing influence from iron or other cause exist in the ship itself. This is therefore the principal distinction between the land and sea compass. In the sea, or *mariner's compass*, Fig. 611, the magnetic needle,

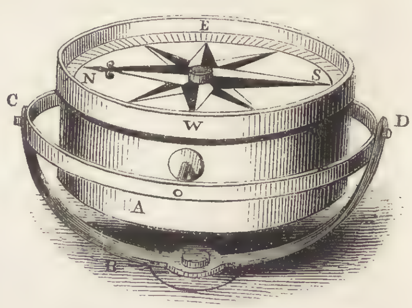


Fig. 611. THE MARINER'S COMPASS.

together with its card, SWNE, is accurately poised on a fine central point within a bowl or case, A, of glass, metal, or wood; and in order to prevent any disturbance from the pitching and rolling of the ship, this bowl is set within a ring of metal, CAD, upon two axial pivots, projecting from its opposite sides, one of which is seen near A. The ring, in its turn, is set also upon axial pivots, at C and D, in a line at right angles to the former, and which are supported either within a second semicircular or vertical ring, CBD, or on pivot notches in two brass plates fixed at C and D to the box or case in which the whole is usually enclosed. [See BINNACLE.] The centre of gravity of the mass is frequently kept far below these axial pivots of suspension by a ring or small mass of lead, attached to the bottom of the compass-bowl. The two brass circles within which the compass-bowl is thus supported are called *gimbalds;* and it is evident that, by these, the card and needle will generally be preserved in a plane perpendicular to that of

the point of suspension. In fact, any rolling motion transverse to the axis C D moves the ring C A D upon the axis C D, and any similar motion transverse to the axis A moves the ring C A D upon the inner axis A; the interior bowl, with the needle and card, being all the while maintained in a vertical position by the force of gravity. This form of the compass, although chiefly employed to guide the mariner across a trackless ocean, has still many other important practical applications. For an account of these, we refer the reader to Sir W. Snow Harris's Treatise on Magnetism, published in Weale's "Rudimentary Series," in which he will find an account of the azimuth compass, the dipping needle, and other magnetic instruments.

COMPASSES, an instrument in its simplest form consisting of two legs, movable about a joint. The extremities of the legs are furnished with points, which may be set at any required distance from one another, and thus be used to measure and transfer distances, and to describe arcs and circles. "The points of the compasses should be formed of well-tempered steel, that cannot be easily bent or blunted; the upper part being formed of brass or silver. The joint is framed of two substances; one side being of the same material as the upper part of the compasses, either brass or silver, and the other of steel. This arrangement diminishes the wear of the parts, and promotes uniformity in their motion. If this uniformity be wanting, it is extremely difficult to set the compasses at any desired distance, for, being opened or closed by the pressure of the finger, if the joint be not good, they will move by fits and starts, and either stop short of, or go beyond, the distance required; but when they move evenly, the pressure may be regulated so as to open the legs to the desired extent, and the joint should be stiff enough to hold them in this position, and not to permit them to deviate from it in consequence of the small amount of pressure which is inseparable from their use. When greater accuracy in the set of the compasses is required than can be effected by the joint alone, we have recourse to the *hair compasses*, in which the upper part of one of the steel points is formed into a bent spring, which, being fastened at one extremity to the leg of the compasses, almost close up to the joint, is held at the other end by a screw. A groove is formed in the shank, which receives the spring when screwed up tight; and by turning the screw backwards, the steel point may be gradually allowed to be pulled backwards by the spring, and may again be gradually pulled forwards by the screw being turned forwards."—*Heather.* There are also compasses with movable points; the end of one of the shanks being formed with a spring, which holds firmly the movable point, or a pencil or ink-point, or a pen-point with a dotting-wheel, or a lengthening-bar, as may be required. To describe small arcs or circles, a small pair of compasses, called *bow compasses*, with a permanent ink- or pencil-point, are used. They are formed with a round head, which rolls with ease between the fingers. For copying and reducing drawings, compasses of a peculiar construction are used, consisting of a double pair of compasses, two legs being above and two below the central joint: the simplest form of these compasses is that called *wholes and halves*, because the longer legs being twice the length of the shorter, when the former are opened to any given line, the shorter ones will be opened to the half of that line. In this way, all the lines of a drawing may be reduced to one-half, or enlarged to double their length. To reduce or enlarge drawings in any required proportion, a beautiful instrument, named the *proportional compasses*, is used. This, together with *beam compasses*, will be described under PANTAGRAPH. For further information respecting compasses, we must refer to Mr. Heather's Treatise, in Weale's "Rudimentary Series." This is the best and cheapest treatise on the use of mathematical instruments with which we are acquainted.

CONCENTRIC, having the same centre: concentric circles are those described about the same point.

CONCRETE. See LIME—MORTAR.

CONE. If a straight line A X, Fig. 612, pass through a fixed point O, and be moved through any curve such as A B C, it will trace by its motion a surface, which is called a *cone*. Of this cone, the point O is the *vertex*; the right line, the motion of which produced the surface, is the *directrix*, and the curve A B C which guides its motion, the *generatrix* of the cone. If the generatrix be a right lined figure, the cone will become a *pyramid*. The most usual form of cone is that whose generatrix is a circle. The *axis* of a cone is a line drawn from its vertex to the centre of its circular base. In a *right cone*, the axis is perpendicular to its base; in an *oblique cone*, the axis is oblique to its base. A pyramid and a cone, whose bases and altitudes are equal, have equal volumes; for since all the corresponding sections parallel to the bases are equal, the cone will be composed of a series of plates, equal respectively to those which compose the pyramid. The volume of a cone is found by multiplying the area of its base by one third of its altitude. If a cone and a cylinder have equal bases and equal altitudes, the volume of the cone will be one third of the volume of the cylinder. The volumes of cones being proportional to the products of their bases and altitudes, and the bases being proportional to the squares of their diameters, the volumes will be proportional to their altitudes multiplied by the squares of the diameters of their bases. The area of the surface of a right cone is found by multiplying the length of its side, by half the circumference of its base. The area of the surface of a right cone, is equal to that of a triangle, whose base is equal to the circumference of the base of the cone, and whose altitude is equal to the side of the cone. If a cone

Fig. 612.

be cut by a plane A′B′, Fig. 613, parallel to its base, the figure with parallel circular bases thus cut off, is called a *truncated cone.* The area of the surface and the volume of a truncated cone, are found by taking the difference of the surfaces, and of the volumes of the whole cone, A O B, and of the cone A′O B′ which is cut off.

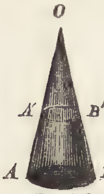


Fig. 613.

A circular cone is produced in the arts by means of the turning-lathe: when the substance to which the conical form is to be given, is kept constantly turning, the cutting tool is moved along the directrix, or side of the cone; as it advances, the circular form is given to the section of the body by its own motion, and the rectilinear form is given to its side by the motion of the tool.

COOLER. See BEER.

COOPERAGE. From the year 70 of the Christian era, the art of making vessels of different pieces of wood seems to have been well known. The invention is ascribed by Pliny to the people who lived at the foot of the Alps. Some of the classical writers on Rural Economy mention such vessels, and describe them as being bound together with circles of wood or hoops. The art was probably introduced by the Romans into Britain, and it seems to have attained its present state of perfection at a very early period.

The occupation of the cooper is divided into several distinct branches. The *dry* cooper makes casks for containing all kinds of goods not in a liquid state, as sugar, currants, flour, &c. The *wet* or *tight* cooper makes casks for all kinds of liquid goods, and this branch is subdivided into *large* and *small* work, which are kept quite distinct. There are also *white* coopers, or those who make tubs, pails, churns, &c.; and there are coopers in *general,* who profess to undertake all kinds of work: it is necessary however, in order to become a skilful cooper, to confine attention to one branch of the trade, and of this the most difficult is that which is devoted to large tight work.

Tight work is made of oak, of which five kinds are used, viz.—Quebec, Virginia, Dantzic, Hambro', and English oak. Small dry casks or *kegs* are chiefly made of Quebec oak.

The figure of a cask is that of two truncated cones or conoids joined together, for the lines are not straight as in cones; but curved from the vertex to the base. The place of junction of the two conoids, or the middle of the cask, is called the *belly* or *boulge,* and the space between the middle and the end, the *quarter.* The wood is chosen from old, thick, and straight trees: the planks are hewn and formed into staves. The French prepare the wood in winter; the staves and the bottoms are then formed, and the cask is *mounted* or put together in summer. Shaping or planing the staves is one of the most difficult, and also the most important parts of the cooper's work. Each stave must form part of a double conoid; it must be broader in the middle, and gradually become narrower, but not in straight lines, towards the two extremities. The outside of the staves across the wood must be wrought into segments of a circle, and be thickest nearer the middle, growing gradually thinner towards the ends. When the staves are dressed and arranged in a circular form, the cooper without attempting to slope them, so that the whole surface of the edge may touch in every point, brings the contiguous staves into contact only at the inner surface, and by driving the hoops hard, he can make a closer joint than could be done by sloping them from the outer to the inner sides. In this, and in giving the proper curve to the staves, consists the principal part of the cooper's art.

In the vaults of various docks are many thousand casks of wines and spirits in bond. The office of *bond*-cooper, as it is called, is an important one; each bond-cooper has the charge of from 1,000 to 2,000 casks, and it is his duty to see that all the casks are in good order, to draw out samples for tasting, &c.

The reader who wishes to follow out the minute details of the cooper's art, is referred to the number entitled "The Cooper," of Mr. Charles Knight's excellent little series, "The Guide to Trade."

COPAL. See VARNISH.

COPPER, (Cu. 32,) a metal known to the ancients, and deriving its name from the island of Cyprus, where it was first wrought by the Greeks. Before the discovery of malleable iron, it was the chief ingredient in the manufacture of domestic utensils, and instruments of war. Copper is sometimes met with in a native state, but more frequently in combination with the metalloids, with oxygen, sulphur, and arsenic. The sulphurets are most abundant, and from them the commercial demands are almost exclusively supplied. The sulphuret combined with sulphuret of iron, forms the well-known *yellow copper* ore. Native copper often crystallizes under the form of small regular octohedrons; these may be also obtained when copper is slowly precipitated from solutions by voltaic electricity. Copper affects the same crystalline form, when a considerable mass melted in a crucible, is left to cool slowly; the part which remains liquid after reposing some time, having been poured off. Chemically pure copper may be obtained by passing a stream of hydrogen over the oxide, heated to redness in a glass tube. If a small quantity of the oxide is operated on in this way, the reduced metal is obtained in thin films, which by reflected light present the characteristic red colour of copper, but by transmitted light are of a beautiful green. Copper is very malleable and ductile; it may be beaten out into thin leaves or drawn out into fine wire. It has great tenacity, being in this respect inferior only to iron. Its density varies from 8.78 for cast copper, to 8.96 for rolled or hammered copper. It has a peculiar taste, and by friction evolves a disagreeable odour. It melts at a strong red heat, which has been fixed by Daniell at 1996° Fahr. At a white heat, it passes off in vapour, which burns in the air with a green flame. At a white heat, copper decomposes the vapour of water. At ordinary temperatures, this metal does not oxidise in dry air; but it changes quickly in moist air; it then

becomes covered with a strongly adherent green crust consisting chiefly of carbonate. Copper changes more quickly if an acid vapour be present. VERDIGRIS is a subacetate of copper, and is formed by placing plates of the metal in contact with the fermenting marc of the grape, or with cloth dipped in vinegar. Heated to redness in the air, copper becomes quickly oxidized, a black scale covering its surface. Dilute sulphuric and muriatic acids scarcely act upon metallic copper, but dilute nitric acid dissolves it readily. Two oxides are known which form salts. The protoxide or black oxide of copper, (CuO,) is the base of the ordinary blue and green salts. When a salt of this oxide is mixed with caustic alkali in excess, a bulky pale blue precipitate of hydrated oxide, (CuO,HO) falls, which when the whole is raised to the boiling point, becomes converted into a heavy dark brown powder: this is anhydrous oxide of copper, for the hydrate is decomposed even in contact with water. Prepared at a high temperature, the oxide is perfectly black and very dense. The hydrated oxide of copper is used as a pigment or colour for paper-staining, for which purpose it is mixed with glue or sise, with the addition of chalk or alumina. Its blue colour, however, soon acquires a greenish tinge.

The suboxide or red oxide of copper, (Cu_2O,) may be procured by heating in a covered crucible a mixture of 5 parts of black oxide, and 4 parts of fine copper filings. There are various other methods of procuring it. It often occurs in transparent ruby red crystals associated with other ores of copper; it is known as *Ruby copper:* one variety known in Cornwall as *Tile ore,* contains peroxide of iron. The suboxide gives a fine red tint to glass, while that given by the protoxide is green.

Among the more important salts of copper may be noticed the *Sulphate* or *Blue vitriol* ($CuO, SO_3 + 5HO$). This salt may be prepared by dissolving oxide of copper in sulphuric acid, or more economically by oxidizing the sulphuret. It forms large crystals of a fine blue colour, which are soluble in 4 parts cold, and 2 of boiling water; heated to 400° it becomes anhydrous, loses its colour and becomes white; if left exposed, it slowly re-absorbs water from the air, and regains its blue colour; or if sprinkled with water heat is evolved, and the blue hydrate is immediately formed. This salt is the source of several blue and green colours, it is used by dyers and calico-printers; also in some kinds of writing ink, but with this inconvenience, that in writing with steel pens, metallic copper is precipitated upon the steel, and the pen gets clogged; it is on this principle, that by immersing pieces of iron in the waters of copper-mines, which often hold copper in solution, metallic copper is recovered. Grain steeped in a solution of this salt, is said to be not liable to the smut, and timber or planks similarly treated, will be preserved from dry rot. Wood-work, cellars, &c., subject to mouldiness should be washed with a solution of blue vitriol. This salt is also a powerful preservative of animal substances, which when imbued with it and dried, remain unaltered.

The commercial sulphate of copper is manufactured in the following manner:—In a wooden vessel lined with stout sheet-lead, oil of vitriol is poured, to which are added *copper scales,*[1] until a saturated solution of sulphate of copper is obtained, the operation being assisted by the aid of steam blown in through a lead pipe dipping to the bottom of the vessel: the mother liquor of a previous operation is then added, and the whole left to crystallize. The crystallizing vessels are of wood lined with lead: they are placed in a warm room, and a crop of crystals is usually obtained in 4 or 6 days. The mother liquor being poured off, the crystals are drained, and packed in casks for sale: in some cases they are previously dried. It is not unusual to add the *pickle* or *dipping-liquor* used by the coppersmith for the purpose of cleaning copper, brass, &c.,[2] to the solution of copper in sulphuric acid; and in some cases the pickle is used alone, for the purpose of furnishing crystals of this salt, the excess of acid being neutralized by oxide of copper.[3]

By adding carbonate of soda in excess to a solution of sulphate of copper, the precipitate is, at first, pale blue and flocculent, but by heat it becomes of a sandy texture and of a green colour. In this state, it contains $CuO_3CO_2 + CuO, HO$. This carbonate is prepared as a pigment under the name of *blue verditer.* Malachite has a similar composition; it is found in great beauty in the Uralian mountains of Siberia. Chloride of copper, $Cu\,Cl + 2\,HO$, is easily prepared by dissolving the black oxide in hydrochloric acid, and concentrating the resulting green solution. It forms green crystals very soluble in water and in alcohol: it gives a green colour to the flame of alcohol. Dichloride of copper $Cu2\,Cl$ is obtained by exposing copper filings to the action of chlorine. It may also be obtained in various other ways. When this salt is moistened and exposed to air it becomes green, and is converted into a compound of chloride and oxide of copper, which has been termed Submuriate of copper or *Brunswick green.*

Of the compounds of copper and sulphur, the most interesting is the disulphuret ($Cu_2\,S$.) It is found as an ore chiefly in primitive countries. It occurs in Cornwall and Yorkshire in great beauty, crystallized and massive. Its colour is grey: its lustre shining and metallic: its sp. gr. 5.69 to 5.73. Its primitive form is a six-sided prism, which passes into the dodecahedron with triangular faces and its various modifications. But by far the largest proportion of the copper of commerce is derived from the ferrosulphuret, or copper pyrites, or yellow copper ore.

(1) Copper scales consist of a mixture of metallic copper with oxides of tha' metal, and are obtained, in the form of thin plates or scales, from the sheets of copper which have undergone the process of annealing by being heated in a furnace or forge. A portion only of these scales is dissolved by the acid; the residue is washed, dried, and sent to the copper-furnace to be melted.

(2) In Birmingham some hundred tons of dipping-liquor are produced every year, and used in the manufacture of sulphate of copper. The salt is very impure: it often contains a large portion of zinc, which may be seen in the form of slender white needles on the surface of the dark blue crystals. Nickel, lead, arsenic, and antimony are also sometimes present in these crystals.

(3) Pharmaceutical Journal for April, 1851.

This occurs in various forms, its primitive crystal being the regular tetrahedron.

The metallurgical history of copper presents so many important and interesting features, that we propose to devote a considerable space to the subject. The methods adopted for procuring the ore and raising it to the surface, stamping, dressing, &c., will be described under METALLURGY—MINING—TIN. Our present object is to give a brief notice of the copper trade, and to detail somewhat fully the various processes concerned in the smelting of the ore.

The copper smelting works of this country are situated at Swansea in the Bay of Bristol; they are by far the largest in the world, they are highly prosperous, and many of the circumstances connected with them are unparalleled in the history of metallurgy.

The ores of metals generally contain a large proportion of matter, the value of which is incomparably less than that of an equal weight of metal contained in them. To save the expense of carriage the ore is usually dressed in the vicinity of the mine, and the position of the smelting works is most commonly determined by that of the metallic lodes. Thus in all the great metalliferous districts, in the Altai, and the Ural Mountains, in Sweden, Norway, Hungary, the Tyrol, Germany, &c., the ore has rarely to travel more than a few miles to the place where it is to be smelted. In the United Kingdom, however, the copper ore is sent by sea from the numerous mines of Cornwall, Devonshire, Wales, Ireland, and the Isle of Man, to South Wales to be smelted; distances varying from 60 to 250 miles, and this traffic has not added more to the expense of smelting than would be occasioned on the continent by a mean transit of 10 times less the distance. Moreover, during the last 20 years, Swansea has been supplied with ores from the shores of Europe, from Cuba, Mexico, Columbia, Peru, Chili, Australia, and New Zealand, so that at the present time there is more copper smelted in South Wales than in all the other countries of the New and of the Old World taken together.

The copper trade of this country is therefore of great importance, although vastly inferior to that of iron: indeed there are as many hands employed in one of our great iron works as in all the copper works of the kingdom. There are 19 copper works in England and Wales, all of which (with the exception of two small works, one in Liverpool and the other in Anglesea,) are situate in the Swansea Valley above the town, or within a distance of 14 miles from it. Swansea owes her distinction in this respect to the possession of a commodious and safe harbour, with a coal field behind it. The Admiralty Hydrographers remark:—"Of all the ports in the Bristol Channel, there is perhaps none more favourably situate than that of Swansea, for it is an important fact, that Swansea harbour is accessible to any stranger that may arrive in the bay when it is blowing too strong for pilots to get off." The width of the bay is about 10 miles, and the town is situate in the centre of the curve.

The ores of Cornwall and Devonshire are sold at or near the mines where they are raised. Foreign ores are brought to Swansea to be sold. The Cornish ores are roughly prepared for sale in the following manner:—When the ores are brought to the surface, they are divided into three portions: the first consisting of pieces about the size of the fist, called *spalling stuff;* the second termed *picking rough*, consisting of such smaller pieces as will not pass through a sieve, named from the size of the meshes, a *three-quarter-inch griddle;* and the third, of all that passes through the sieve, called *shaft small*. The larger pieces being broken to about 1½ inch square, are mixed with the picking rough, and the whole is divided into *prills*, or lumps of pure ore; *dradge*, or ore mixed with other substances; and *halvans* or *leavings* which contain but a small quantity of ore. The prills are broken into pieces of about ½ inch square, which is performed by females with large flat-polled two-handed hammers; this portion of the ore is then ready for the market. If the dradge contain but little iron pyrites, it is broken to a still smaller size than the prills, and is then jigged in a sieve of about 5 holes to the square inch: by which means it is separated into 4 parts: 1, that which passes through the sieve, called *hutch-work*, which is usually fit for sale; 2, that portion occupying the bottom of the sieve, called *ragging*, which is also in a marketable state; 3, the middle part of the contents of the sieve which is again broken and jigged; 4, that at the top of the sieve, which is put among the leavings. If the dradge contain much iron pyrites, it is *picked* by females and children: the pieces being broken to about ⅝ inch square, and the impurities picked out by hand. By continuing these operations of picking, breaking, and sifting, the ore is rendered fit for sale. Some of the ores are so soft, that exposure to water would occasion loss. The leavings or refuse are, however, sometimes stamped and buddled in the same manner as tin ore. [See METALLURGY—TIN.]

The determination of the value of the ores offered for sale is difficult, and it is admitted, that the precise results obtained by the chemists, are inferior in practice to those adopted by the mining agents. Although these may be only an approximative analysis, and occasionally lead to a depreciation in the price offered for the ore, the mine owners are too well aware that their interests are identical with those of the smelters, to disturb the method of selling the ores which has existed for very many years. The plan adopted is as follows:—When the miners of a certain place have to sell a quantity of ore, advertisements are inserted in the local journals appointing the days for sale, and the days when specimens of the ore may be taken. The places of sale are Camborne, Redruth, Truro, and Pool, on account of their central position. The sales always take place on a Thursday. Each of the Welsh copper companies has two agents in Cornwall, one of whom takes the sample, of which the other makes the assay. On the day appointed the agents meet at the mine, dine at the expense of the owner, and take samples. The weight of each lot rarely exceeds 100 tons, and is seldom less than 5 tons: it is usually

between 20 and 80 tons. During the 15 days between this and the day of sale, the agent makes his report to and receives instructions from his employers for the regulation of his biddings. On the day appointed for sale, the agents meet the mine-owners at an inn in one of the above-named towns; the meeting is usually presided over by the owner who has the largest quantity of ore for sale. The sale commences at noon with closed doors, and the proceedings are conducted in a very quiet manner, although as much as from 20,000*l.* to 40,000*l.* worth of ore is about to be contended for. The chairman begins by reading the number of tons and the description of the first lot on his list. Each bidder writes on a slip of paper called a *ticket*,[1] the price which he has to offer and gives it to the president. The weight of each lot not having been rigorously determined, the price offered refers to the ton of *dry* ore. All the tickets being collected, the president reads slowly the prices offered, and the agents enter them in papers ruled for the purpose. The president assigns the lot to the highest bidder, and states the difference between the highest and the lowest price offered. Should any two agents make the same offer, the lot is divided equally between them. A second lot is then put up, and 10 minutes is allowed for the agents to make their calculations, which may be to a certain extent influenced by the result of the first sale. The following is a specimen of one of the papers as filled up by the agents while the president is reading over the tickets. The prices underlined are those at which the different lots were sold.

SALE AT REDRUTH, 20TH OCTOBER, 1842.

	First Lot.			Second Lot.			Third Lot.			Fourth Lot.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
1st Company....	5	4	6	7	13	0	4	12	6	4	5	0
2d ,, ...	5	6	6	7	14	6	4	8	6	4	4	0
3d ,, ...	5	12	6	8	4	0	4	14	0	4	9	6
4th ,, ...	5	13	0	8	3	0	4	10	0	4	6	0
5th ,, ...	5	11	[illegible]	8	5	6	4	13	0	4	11	6
6th ,, ...	5	11	0	8	0	0	4	12	0	4	6	0
7th ,, ...	5	11	6	8	0	6	4	14	6	4	12	0
8th ,, ...	5	14	0	8	1	0	4	15	0	4	8	6

After the sale the agents proceed to the mine, and the lots are delivered: the weight of each lot is exactly ascertained in the moist state, and the agent then finds, by experiment, what deduction is to be made for moisture. One month after the sale the founders forward to the mine owners bills payable one month after date, for the amount of their respective purchases. In the year 1848 the number of tons of copper ore sold in Cornwall amounted to 153,120, which produced 873,436*l.* 10*s.* 6*d.* In the same year 47,611 tons of foreign copper ores were sold at Swansea, which produced 641,056*l.* 10*s.* 6*d.*: these fetch a higher price than the English ores, not only on account of many of them being richer, but also from their being higher dressed before they are shipped for England.

(1) Hence this system of sale is called *ticketing*, and the days of sale *ticketing days*.

The mines of South America, the foreign West Indies, and Australia, which supply the ores, are worked chiefly by English adventurers, the head quarters of the several companies being in London. These companies charter vessels of large burden to convey the ores to Swansea, where they are stowed in yards, crushed, sampled, and sold to the copper masters at the ticketings. Some of the ores are crushed by passing them through rollers. A correspondent of the *Morning Chronicle* describes a visit to one of the ticketings which are held every fortnight at the chief hotel in Swansea. He says:—

"The proceedings were characteristic, and were remarkable for the total absence of that kind of excitement which often accompanies business transactions on so extensive a scale. At a long table, arranged with blotting-paper, pens, and ink, as at a committee meeting, the proprietors or agents of the copper works take their seats. At 12 o'clock the chairman takes the chair, and opens the business by saying: 'I'll take offers for the first four lots of Cobre, Burra Burra,' or whatever may be the number of the lots and the kind of ore to be sold in the first group. Upon this the buyers, who have previously had each lot assayed, and ascertained its worth, enter on a small billet of paper the amount they bid per ton for each lot, fold the paper, and hand it to the chairman. When all the biddings are received, the chairman opens them in a prescribed order, and calls out the bidding, which the parties present enter into a blank form supplied for the purpose; and when he has gone through the whole, he names the buyer, and calls out the 'excess,' *i.e.* the sum per ton which the buyer's bidding exceeds that of the highest bidder below him. The chairman then offers the next group of 'parcels,' and the same routine is pursued as on the first occasion. Scarcely a word is spoken. In this manner sales, in the course of an hour, are effected, amounting to between 20,000*l.* and 50,000*l.* At the ticketing held on 3d January, there were thus sold 1,447 tons of Cuba and South Australian ores, the proceeds amounting to 28,925*l.* 4*s.* 6*d.* The cargo of Burra Burra ore, brought by one ship, 'The Ancient Briton,' appears to have realized 14,666*l.* 4*s.* 6*d.* of the above total. What struck me as very remarkable, was the nicety with which the calculations of the worth of the ores had been made by the buyers. The system of assaying must have been carried here to very high perfection; for the 'excess' of the highest bidder over the bidder next below him in the case of 15 lots which I saw sold, was in two instances 2*s.* 6*d.* a ton, in five 1*s.* 6*d.* a ton, in two 1*s.* and in six only 6*d.* a ton. The price given per ton for Irish ores sold at the ticketing I attended, varied from 8*l.* 10*s.* 6*d.* down to 3*l.* 15*s.*"

The perfection in the system of assaying, which the writer here speaks of, ought rather to be called that kind of practical knowledge which results from long experience, guided and modified by the condition and prospects of each company, and the price of copper in the market.

The founders have dépôts in the principal ports of Cornwall and Devonshire, where the ore is stored. It

is transported to Swansea in vessels of 100 to 150 tons, which draw very little water, so that they can discharge their cargoes at all states of the tide in the yards of the companies, which are nearly all situated at the edge of the river, R, Fig. 620. The average cost of freight is about 4*s.* per ton, and the vessels return to Cornwall with cargoes of Welsh coal, the freight of which pays the greater portion of the expenses of the voyage. Cornwall and Devon send on an average to Swansea 165,000 tons of ore, and Ireland 35,000 tons. A vessel of 130 tons arriving at one of the company's quays at 5 A.M., will have discharged her cargo by 3 P.M.

Two-thirds of the ore which is brought to Swansea consist of copper pyrites; the remaining third consists of the green carbonate, the red and black oxides, the hydrosilicate, the phosphate, the arseniate, and native copper: most of these are associated with quartz and iron pyrites. These ores have been grouped into five classes according to their chemical composition, and the proportion of copper contained in them:—

1st Class,—Copper pyrites containing a large proportion of iron pyrites, and very little oxide of copper. The gangue is quartz and earthy matters. The amount of copper varies from 3 to 13 per cent.

2d Class,—Copper pyrites similar in composition to the preceding, but containing from 15 to 25 per cent. of copper.

3d Class,—Copper pyrites containing a very small proportion of iron pyrites, and substances which injure the quality of the copper, but a large proportion of oxide of copper. Their gangue is essentially quartzose. They contain from 12 to 20 per cent. of copper.

4th Class,—Ores composed principally of oxides of copper, mixed with copper pyrites, and feather copper. The gangue is quartzose, and the value in copper varies from 25 to 45 per cent.

5th Class,—Very rich ores, free from sulphur and deleterious substances. The gangue is quartzose. They contain from 60 to 80 per cent. of copper in the form of native copper, oxide, or carbonate. These choice ores come chiefly from Chili.

The founders also purchase the roasted ores of Chili, and the copper scales and clippings furnished by many workers in copper, also the slags of old furnaces, which still contain a proportion of copper. The fluxes are silica, clay, fluor spar, &c. The last mineral is obtained from the lead mines situated on the banks of the Tamar. The quartz sand, a very large quantity of which is used for the soles of the furnaces, &c., is obtained in abundance on the spot. Fire bricks, for the furnace, are procured from Stourbridge.

That important article in all metallurgic processes, the fuel, is chiefly the anthracite, or stone coal of Wales, which, from the absence of bitumen, produces during combustion little or no gas, and, consequently, very little flame. The value of this coal, compared with the caking varieties, is so small that it will not pay the cost of carriage out of the country, except by way of ballast, as already noticed. Every year about 900,000 tons of coal are raised in Wales, two-thirds of which are composed of dry, or non-caking coal; and in getting out this coal a nearly equal quantity of small coal is produced. As this dry anthracite coal does not cake by the action of heat, but crumbles to powder, it cannot be converted into coke; it is of no use in the roasting furnaces, as they are usually constructed, because it slips through the bars when added to the fire in moderate quantity, and obstructs the draught, and extinguishes the fire when added in large quantity. The difficulties of using such coal in reverberatory furnaces, such as are employed in Wales in the smelting of copper, have been overcome in a very remarkable and highly ingenious manner, as will be noticed presently.

In the smelting of copper ore, as practised in Wales, there are ten fundamental operations, viz.—1, The Calcination of the ores; 2, Melting for coarse metal; 3, Calcination of coarse metal; 4, Melting for white metal; 5, Melting for blue metal; 6, Re-melting of the slags; 7, Roasting of white metal; 8, Roasting for regule; 9, Roasting; 10, Refining and toughening.

First Operation.—All the ores of the first class are roasted, or *calcined* as it is called in Wales, and the operation is conducted in a reverberatory furnace, of which a section and plan are shown in Figs. 615, 616. This calcining is necessary on account of the presence of a large quantity of iron pyrites, which would not allow the ores to be raised in value as respects their copper, by mechanical processes merely, such as are adopted with so much success with the ores of other metals. The presence, also, of arsenical sulphurets indicates the necessity for calcining. The ores are conveyed from the dépôts near the quays, *q q*, Fig. 620, along an inclined plane, I, and are then wheeled to a tram-way, *s s*, Fig. 620, and *t*, Fig. 615, situated over the calcining furnaces, and the charge is thrown into two large hoppers of plate-iron, H H, Fig. 614 and 615: these are closed at the bottom by means of a plate, on withdrawing which the charge falls upon the sole of the furnace *s*, Fig. 616. This sole, which is composed of fire bricks, is 23 feet long, and 23 feet wide. The vault of the furnace descends by a rapid slope from the fire, to C, the entrance of the flue, *f*, Fig. 615. Two sides of the furnace contain each two doors, Fig. 614, which allow the men to spread the charge, and work, or *rabble* it from time to time; a hole, *o*, Fig. 614, situated near the bridge, *b*, admits a quantity of air, which can be regulated by means of a register plate. There are four oblong openings, *h h*, in the sole, closed during the calcination with iron plates, on withdrawing which, the charge can be raked out into the reservoirs, R.

It is necessary in roasting ores that a flame should be produced, and reverberated, or reflected down upon the mineral: this is usually done by burning a bituminous fuel in the grate, and the flame thus produced is reverberated upon the ore by the peculiar form which is given to the vaulted top of this kind of furnace, and also by the draught excited by a tall chimney. But as anthracite does not produce a flame, some contrivance was necessary to apply to the useful purposes of the copper smelter the immense stores of this mineral with which South Wales is supplied. When anthracite is raised to a very high temperature it forms a vitreous scoria, or *clinker*, which, in the

ordinary form of furnace, occasions great loss and embarrassment, by choking up the bars of the grate, and combining with the iron of the bars leads to their rapid destruction. In the Welsh furnaces these clinkers are made to perform the office of the bottom bars of an ordinary furnace, supporting the fuel, and limiting the supply of air through the spaces between every two bars. The clinkers themselves are supported on iron bars placed at a considerable distance apart; these do not perform the usual office of the bottom bars, but are merely supports for the clinkers, which are piled up upon them so as to form a layer from 12 to 16 inches thick. Above this support the fuel is in full combustion, and forms the hottest part of the fire, and here it is that fresh clinkers are being continually formed, and in the act of formation they cake with the numerous fragments of small coal heaped up above them. As this new clinker forms, it gradually descends towards the bottom of the fire, and becoming chilled by the rapid current of ascending air which supports the combustion, splits and cracks into numerous fragments. In this way new channels are formed sufficiently large to admit the ascending air in powerful jets, which urge on the combustion, but not large enough to allow the small coal to fall out and escape. The *calciner man*, who has charge of the operation, disengages a few of the bottom clinkers as they accumulate, so as to preserve certain relative proportions between the different parts of the fuel, which experience has found to be best adapted to the successful working of the fire.

The anthracite, which is chiefly used as the fuel, is mixed with about $\frac{1}{4}$ of its weight of small bituminous coal, which, caking with the anthracite, and swelling up by the heat, preserves in the mass the requisite degree of porosity. The layer of anthracite above the supporting clinkers is about 12 inches thick. The air traverses this layer through a multitude of channels, formed by the cracks in the clinkers: its oxygen is entirely converted into carbonic oxide, and this gas mingled with the nitrogen, streams through the furnace. Under ordinary circumstances the carbon of fuel under combustion is converted into carbonic acid, which is an uninflammable gas, and prevents the combustion of other bodies. Nitrogen, also, will not support combustion. By the above arrangement, however, the carbonic acid, which is formed by the combustion of the fuel, is deprived of a proportion of its oxygen, and is converted into the inflammable carbonic oxide before, or just as it escapes into the vault of the furnace. But its inflammable property would not, under ordinary circumstances, be displayed here, for it is accompanied by nitrogen, which will not support combustion, and the sulphuretted and arseniuretted hydrogen gases liberated by the calcining ore, although combustible themselves, will not support combustion. In order, therefore, to enable the carbonic oxide to burn, it is necessary to supply it with a supporter of combustion, such as the oxygen of the atmosphere; and for this purpose an opening, o, Fig. 616, is made through the wall of the furnace, just above the ore; each of the four doors, two of which are seen in Fig. 614, is also furnished with a small hole, *o*; through these apertures the air streams with considerable force, depending, of course, upon the draught of the chimney, and supplying oxygen to the carbonic oxide, the whole surface of the ore is played upon by a thin sheet of flame, which burns only on its under surface, while its upper surface, or that of the carbonic oxide which supplies it, is in contact with gases which do not support combustion. In this

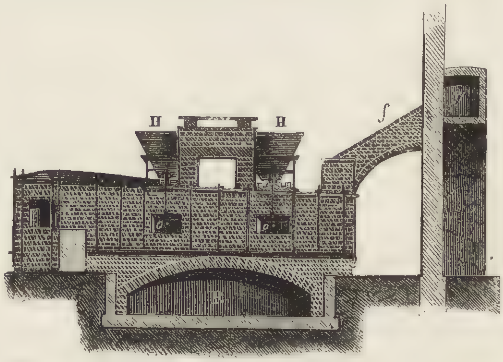


Fig. 614. VIEW OF CALCINING FURNACE.

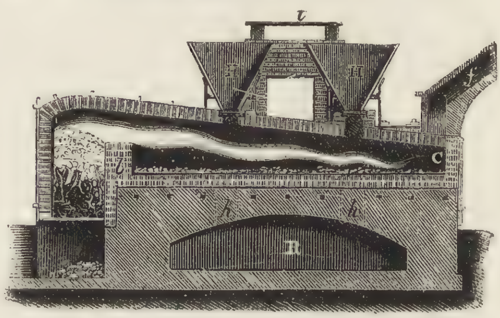


Fig. 615. SECTION OF CALCINING FURNACE.

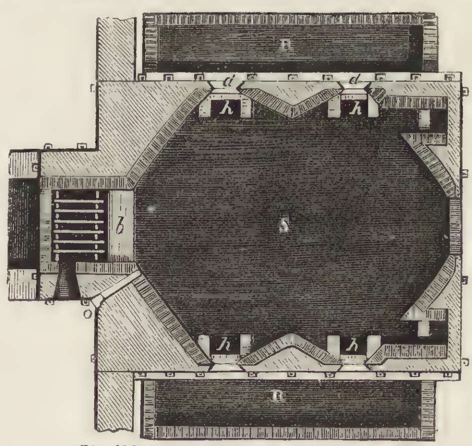


Fig. 616. PLAN OF CALCINING FURNACE.

way the calcination proceeds, and all the gaseous products are, at length, discharged into the chimney by means of the flue, F. The whole of this arrangement is exceedingly beautiful and instructive; indeed, we can scarcely conceive a more difficult problem, especially as the economical calcination of the ore requires the furnaces to be of very large size, and such fuel as anthracite, which burns with scarcely any flame, would

seem, at first view, to be the worst that could possibly be chosen for heating large surfaces, and for so moderating the heat as to maintain nearly the same temperature over a surface of nearly 23 feet square; it would naturally be supposed that an excess of temperature would prevail in the region near the fire. All these difficulties, however, are completely resolved by converting the combustible into carbonic oxide, and diffusing this gas over the whole surface of the sole, and then causing it to burn slowly, by admitting a current of air distinct from that which traverses the fire.

Each charge of ore weighs 3.45 tons. It is introduced into the furnace by pulling out the iron plates at the bottom of the hoppers; these are immediately replaced, and the ore is distributed over the sole in a uniform layer by means of long iron rakes, introduced in succession through each of the 4 large doors, Fig. 614. The charge is made up of a mixture of ores, according to the judgment and experience of the smelter. Some of the ores have been dressed and washed; others have been simply crushed, but not powdered; the largest fragments not exceeding the size of a nut. The temperature of the furnace requires to be carefully regulated; if too high, the ore would become pasty, and a superficial glass of sulphur and oxide of iron would form and delay the process. At a properly-graduated temperature the iron pyrites, without ever becoming soft, is decomposed in concentric layers, which allows the oxygen to penetrate through the porous, pliable mass of ferric oxide, which is being constantly formed, and, combining with the sulphur, forms gaseous compounds, which are driven off. The fusion of the ore goes on gradually diminishing as the pyrites loses its proportion of sulphur, which is replaced by metallic oxides. The heat can then be increased without any fear of softening the materials; and when, at the end of $11\frac{1}{2}$ hours, the charge is raked out, the furnace is at its greatest heat. It is not necessary to allow the furnace to cool before putting in a fresh charge, as is done in many other metallurgic operations, because the large mass of ore, 69 cwt., absorbs the excess of temperature. A quarter of an hour after the charge is introduced, the furnace has sunk below a red heat; the moisture of the mineral is rapidly disengaged, and even sulphurous fumes are given off in the vicinity of the fire.

Each furnace is attended by two calciner men, each man working 24 hours alternately. During the $11\frac{1}{2}$ hours of calcination, one man attends to the furnace; but at night, when a new charge is required, two men from two contiguous furnaces assist, so that the furnace may be cooled as little as possible by keeping the doors open. The charge being spread over the sole, the calciner man rests for a short time, and then begins to urge the fire, which, during the previous hour, had become somewhat slackened. He examines the state of the clinkers, and cautiously removes those which prevent the access of air, re-opening with the point of an iron rod the air channels; he next throws upon the fire a charge of coal, and then closes up the fire-door hermetically, by heaping up against it the coal required for the next charge, which is added after an interval of 80 minutes.

An hour after the commencement of the operation, the sulphurets are in full decomposition; this action is, however, confined to the upper portion of the ore, which is directly exposed to the action of the flame, and the oxygen of the atmosphere. This oxidation of the sulphurets disengages a considerable quantity of heat, which favours the operation. Two hours after the commencement of the operation, the calciner man renews the surface of the ore by tracing over the whole extent of the mass a series of parallel furrows. This operation is performed with a long iron rake, called a *rabble*, and the operation itself is termed *rabbling*. It is performed in about 12 minutes the 4 doors of the furnace being opened in succession for the purpose. During the night the calciner men sleep near their respective furnaces, but a watchman goes round every 2 hours to call up the men for the rabbling.

$11\frac{1}{2}$ hours after the commencement of the operation the ore is raked out into the reservoirs, RR, Fig. 616. This is a very painful operation, for the ore, having lost only one half of its sulphur, coming in contact with the external air at this high temperature, discharges considerable quantities of sulphurous and sulphuric acids, which become diffused all around, and render respiration almost impossible to persons who have not been accustomed to these deleterious fumes. Indeed, the men themselves suffer greatly; they cover the mouth and nostrils with a handkerchief, and occasionally rush to a distance to inhale a less impure air. A new charge being given to the furnace, the operation is repeated as before.

By comparing the first of the following tables[1] with the second, the changes which have been effected on the ore will be understood.

	Substances Employed.	Absolute Weight.	Relative Weight.
Crude Ore.	Oxide of Copper, isolated or combined	3.2	0.004
	Copper pyrites	194.2	0.227
	Iron pyrites, Fe Su_2	191.9	0.224
	Various sulphurets	8.7	0.010
	Ferric oxide	5.2	0.006
	Various oxides	2.3	0.003
	Quartz and silica	294.4	0.343
	Earthy bases	16.0	0.020
	Water and carbonic acid in combination	4.2	0.005
Atmospheric oxygen		135.0	0.158
		855.1	1.000
	Products.		
Calcined Ore.	Oxide of copper	46.2	0.054
	Copper pyrites	96.0	0.112
	Sulphuret of iron, Fe_2 Su_3	95.8	0.112
	Various sulphurets	5.1	0.006
	Ferric oxide	100.2	0.117
	Various oxides	5.2	0.006
	Sulphuric acid in combination	9.5	0.011
	Quartz and silica	294.4	0.343
	Earthy bases	16.0	0.020
Gaseous products	Sulphurous acid	182.5	0.214
	Water and carbonic acid	4.2	0.005
		855.1	1.000

(1) The tables contained in this article are from analyses made at Swansea by M. F. le Play, Professeur de Métallurgie à l'Ecole des Mines, and given by him in an elaborate article on the smelting of copper, contained in the "Annales des Mines" for 1848, to which we have been considerably indebted in this article.

The above results may be expressed still more concisely; thus—

Substances Employed.		Products.	
Crude ore	0.842	Roasted ore	0.781
Atmospheric oxygen	0.158	Sulphurous acid	0.214
		Water and carbonic acid	0.005
	1.000		1.000

The total annual weight of ores smelted in South Wales amounts to about 200,000 tons, from which about 46,000 tons of sulphur is expelled to waste, and this produces about 92,000 tons of sulphurous and sulphuric acids. Every day the Swansea works project into the air 188 tons of these acid gases, the noxious influence of which extends to a considerable distance: the aspect of the country proves that the fertility of the soil is thereby considerably diminished, especially in the direction of the prevailing winds. The action on animal life, although not so evident, is no less certain. Where the smoke is so diluted by diffusion that grasses can grow, the cattle that feed on them and the sheep pastured on them are subject to luxations and enlargements of the joints, and a metallic coating is given to their teeth. The gases given off from the numerous chimneys of the works form a white cloud, so thick as greatly to diminish the transparency of the air, and when the gases are beaten down by the wind it is sometimes scarcely possible to discern objects a few yards distant. The clouds continue for a long time before they are dissipated in corrosive rain, and they may sometimes be seen after having been driven 3 or 4 miles from the works. Their opacity is probably due to the mutual condensation of the two transparent gases and the aqueous vapour of the atmosphere.

The flues of the various calciners discharge their contents into a gallery, *g*, Fig. 614, where the smoke, being somewhat cooled, deposits some of its solid matter, which, to a certain extent, diminishes the evil. But the smoke of the copper works contains other ingredients besides the principal ones above named. In a tract on this subject, Mr. Vivian gives the following particulars:—"Copper-smoke, or what may be properly considered under that head, as being peculiar to the operations in a copper-work, may be said to consist of the following substances or chemical compounds, formed during the calcining processes by the evolution of substances contained in the ore:—1, Sulphurous acid; 2, sulphuric acid; 3, arsenic; 4, arsenious acid; 5, fluoric compounds, and chemical impurities. Of the above substances, the first two are formed by the combustion of the sulphur. The sulphurous acid, which is by far the most abundant, is evolved in the state of a pungent and penetrating gas. The sulphuric acid, which is composed of sulphur combined with more oxygen than exists in the sulphurous acid, and water, appears as a dense white vapour. The arsenical contents of the copper ores expelled by heat, appear partly as arsenic, in the metallic state, partly as combined with oxygen, forming arsenious acid or white oxide of arsenic: in both cases it assumes the form of vapour. The fluoric compounds are produced by the decomposition of the fluor spar or fluate of lime during the chemical changes occurring in the calcination of the ore. [See Op. II.] The property of fluoric acid to act on silica is well known, and probably if the contents of the flue from the calciner's were accurately examined, silicated fluoric acid gas and hydrofluoric acid would be formed. The mechanical impurities consist of the fine particles of the ore carried over by the draught of the furnaces. They may contain a portion of copper, but the quantity of this is unquestionably very small." In some of the works, lofty stacks have been erected to carry the smoke so high as to become greatly diluted with the air before it reached the ground; but it is stated that the effect of this plan was to increase the evil by diffusing the smoke over a wider area. The plan of passing the smoke through showers of water, as recommended by Sir Humphry Davy and others, has also been abandoned, and it is stated that all the plans hitherto devised for rendering the smoke innocuous, are so expensive, that if adopted it would be impossible to carry on the trade. The prosperity of the town depends so much on the copper-works, that the inhabitants are content to put up with a positive inconvenience rather than by indicting the proprietors, compel them to seek another locality, and take away a trade which has so greatly benefited the town and neighbourhood.

Second Operation.—The object of the second operation is to separate the ore from its gangue, and to get rid of a portion of the oxide of iron which abounds in poor calcined ores. The action of a very high temperature upon the charge is to separate its component parts into three distinct portions: 1, the whole of the copper, or nearly so, is collected in a matt, consisting essentially of sulphuret of copper and sulphuret of iron; 2, a scoria or slag in which the earthy matters, oxide of iron, and other fixed products are collected; 3, gaseous compounds composed essentially of sulphurous acid and other volatile matters, formed by the mutual reaction of the substances employed under a high temperature. The most difficult and also the most important part of this operation is to concentrate all the copper in the matt, for as the scoria which is produced is thrown away as worthless, any portion of copper contained in it is thus lost.

The charge is composed of calcined ore from Op. I., and of some of the scoria rich in copper from Op. IV. V. and VII. which contain substances of easy fusibility, such as silicate of iron, whereby the fusion of the quartz and of the oxide of iron which abound in the ores is greatly promoted, and which, but for this, would react with difficulty on each other. Fluor spar is also added as a flux, and there are also certain earthy matters produced by the action of the charge on the sole and walls of the furnace. The fuel used is a mixture of 0.68 anthracite, and 0.32 of bituminous coal. Each furnace is served by two men, who work 12 hours each: each charge is in the furnace 4 hours, so that 3 charges are made during the 12 hours. The successful working of the furnace depends on the skill and attention of the men, and the older

metal-calciner man as he is called, is allowed to choose his own mate. The night work is undertaken by each on alternate weeks. The fire is of the same form and dimensions as in Op. I. but it is managed differently. The base of the fire consists of a thick mass of clinker, through which the air streams in powerful jets, and in larger quantity than in Op. I., so as to produce a much higher temperature. A small hole in the furnace door allows the workman to watch

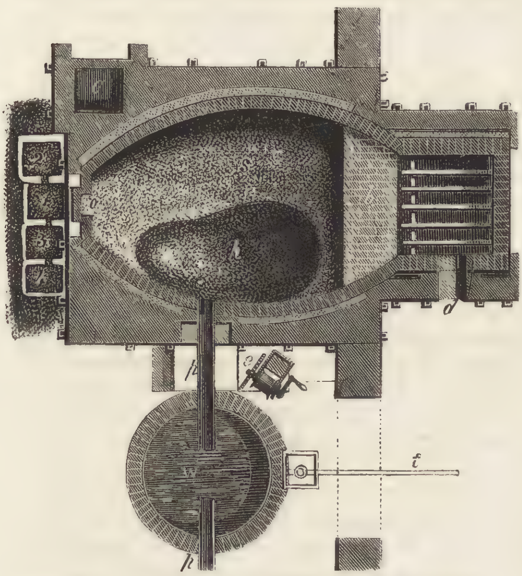


Fig. 617. PLAN OF COARSE-METAL MELTING-FURNACE

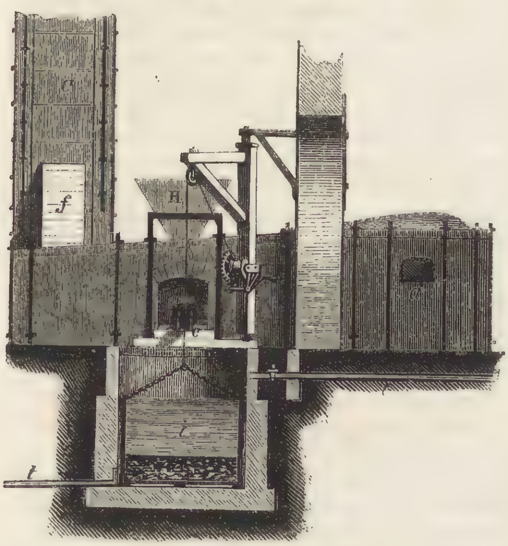


Fig. 618. COARSE-METAL FURNACE.

the process, and he usually estimates its success by the intensity of the light. If this diminishes, the fire has too much or too little solid fuel upon it, or the gases which issue from it are not in the proper proportion to form the highest attainable temperature. If there be too much fuel on the fire (as would be the case if the charge of fuel were not added after the proper interval, but were heaped up at a later period,) the man rakes out some of the clinker, and thus increases the supply of air. If there be too little fuel, the remedy is to divide the charge of coal into several portions, and to add a portion frequently. A diminution of temperature is fatal to the success of the operation, for the charge under such circumstances becomes fused to the sole, and it requires a considerable outlay of time and fuel to restore the mass to its state of fusion. Indeed, the management of the fire in this operation requires tact and judgment: the supply of air must be carefully regulated, for if in excess, a short flame will be produced, not sufficient to reach to the extremity of the furnace.

The interior capacity of the furnace is about 3 times less than that of the calcining furnace, Op. I., nevertheless a very much larger quantity of fuel is consumed. The quantity of coal consumed in 12 hours amounts to 1.677 tons, to burn which requires 1.635 ton of oxygen or 7.106 tons of atmospheric air. The results of the combustion are therefore :—

Combustible gas, produced by the distillation of the coal	0.356
Carbonic oxide	2.861
Nitrogen	5.471
Clinker	0.095
	8.783 tons.

The chimney is of large size, and the gases pour into it at a very high temperature. There is no lateral opening in the flue to cool the current, as at *g*, Fig. 614, and the single opening through which the charge is drawn out, is carefully closed during the operation. A door, at the extremity of the furnace, allows the workmen to elaborate the charge by means of a long rake, and the effect of opening this door is not to cool the furnace, because, although the draught is thereby suspended, yet the cool air rushing in to supply the fire, escapes not into the furnace, but into a side opening. The second charge is introduced immediately after the first is withdrawn; the calcined ore, Op. I., and the flux are poured into the hopper above, and so let down into the furnace; the scoria, which is in large lumps, is thrown in through the door. The composition of the charge varies with the nature of the ores; the scoria from Op. IV. V. and VII. accelerate the fusion, and the metal-calciner men are consequently very eager to get it. This kind of slag has increased in quantity during the last 20 years, in consequence of the importation of the rich foreign ores. The weight of refractory matter in each charge usually varies from 1.05 ton to 1.20 ton, and the weight of scoria assisting the fusion 0.15 to 0.20 ton. The following is an average composition of a charge :—

	Tons.	Tons.	Tons.
Calcined ore	0.896	1.000	1.122
Crude ore	0.104		
Fluoride flux		0.051	
Scoria of the same operation		0.071	
Fusible scoria from Op. IV.		0.106	0.178
,, ,, Op. V.		0.063	
,, ,, Op. VII.		0.009	
Total			1.300

The workman begins by letting fall on the sole 1.051 tons of ore and flux; he then closes the funnel

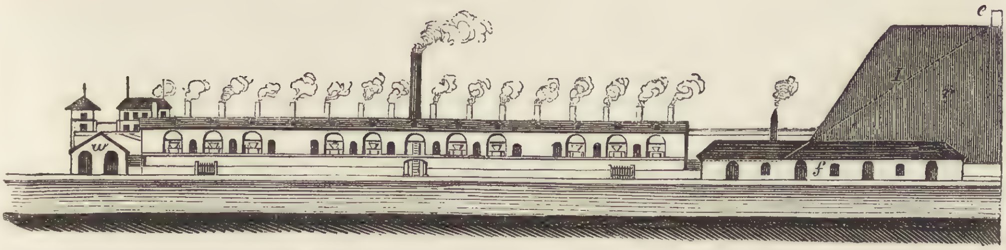


Fig. 619. ELEVATION OF A SWANSEA COPPER-WORK.

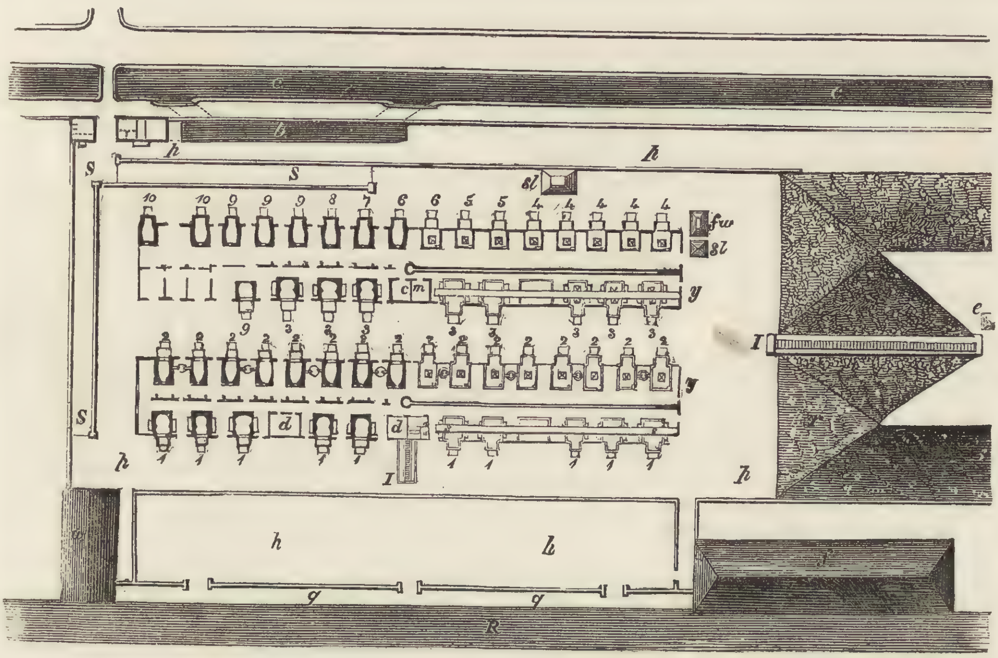


Fig. 620. GROUND-PLAN OF THE SAME.

R River by which the ores are conveyed.
q q Landing quays.
h h Heaps of ore.
I Inclined plane.
p p Sloping terrace.
s s Tram-way over the calcining-furnaces, No. 1.

Nos. 1—10. Furnaces employed in the various Operations I to X.
S S Slopes.
w Warehouse. *f* Rolling-mill.
i i Dépôts of ore from Ops. II, IV., & VI.
f w Heap of furnace-waste.
sl Heap of slag.

y y Yards where slags are sorted.
r Rubbish heaps of slags raised up the inclined plane I by means of the small engine *e*.
C Canal by which coals, &c. are brought.
b Canal basin.
p p Quays for landing Coals, &c.

and the damper of the flue, and by means of a rake rapidly spreads the charge in a uniform layer over the sole. Then taking in his hand the largest pieces of scoria heaped up near the furnace door, he throws them in, scattering them about with tolerable regularity; he then lowers the door, and carefully excludes all access of air thereby by luting it to the wall. The charge is then left for $3\frac{1}{2}$ hours to the influence of the heat, and the man devotes his time to the management of the fire, and the conveyance of the different materials required for the use of the furnace. He detaches from time to time fragments of clinker which fall into the ash-pit, and he keeps open, by means of a pointed iron, the central channel of the fire, which has a tendency to become choked up; a fresh supply of fuel, weighing 0.168 ton, is added about every 72 minutes, and this charge is twice the thickness of the charge in Op. I.

The men of 4 furnaces usually unite in bringing the ore, flux, &c. to the furnaces. It is to the interest of the men, who are paid by the charge, to pass as many charges as possible through the fire within a given time, and if left to themselves, they would take a short supply of the refractory minerals, and lessen the weight of the charge. A foreman is therefore stationed near the weighing-out scales, who makes an entry of every charge.

About half-an-hour after the charge has been introduced, the superficial layer of scoria begins to fuse, and forming liquid furrows among the powdered materials of the charge gradually filters through them, or collects in little ponds. The quantity of fluid silicate rapidly increases, and it soon begins to foam in consequence of the formation of gases below it, and escaping up through it; this agitation brings into more intimate contact the fluid silicate, and the

substances which compose the scoria in process of formation, assisting at the same time in reducing it to a fluid state, while the elements of the matt are by the separation of the materials of the slags brought together, and begin in their turn to react upon each other, leading to the production of gaseous compounds. By degrees, the fusion and consequent separation of the slag and of the matt are accomplished, the matt occupying the lower surface of the sole, and the lighter and more bulky scoria floating on its surface. In 3½ hours, the metallurgic reactions appear to have ceased; a few bubbles of gas rise here and there on the surface and burst; around the edge of the sole may also be seen floating foam-like masses which have escaped liquefaction; the man observing these, opens the door and rabbles the charge, detaching these masses, which fall into the fluid scoria and dissolve. The rabbling being completed, the man closes the door, lets fall some clinker, and arranges his fire so as to produce the maximum of heat. He then prepares for the *casting* of the scoriæ or slags, for which purpose he spreads out a quantity of sand, which has been heaped up on the ground before the door, and having levelled its surface, he digs in it 4 rectangular cavities 1, 2, 3, 4, Fig. 617, in which the scoria is received and moulded. The matt is drawn by the channel *p*, Fig. 617, and the slags by the door at *o*. These are allowed to pour out first into No. 1; when this is full it pours over by a side channel into No. 2, and then into No. 3, and when these are full, No. 1 begins to pour into No. 4, by passing over a channel a little more elevated than the others.

A quarter-of-an-hour after the rabbling, the man prepares for the casting of the matt by cautiously tapping with a pointed iron the orifice communicating with the lower part of the sole. A thin stream of liquid matt issues out and falls into a cylindrical iron vessel immersed in a well, w, supplied with cold water by the pipe *t*, the effect of which is to granulate the metal, and to divide it into portions of about the size of hempseeds, the largest not exceeding that of a bean. The man then opens the door of the furnace, and draws out the slags into the mould already described; this part of the process requires considerable care, in order to separate the slags from the matt. The basis of this scoria is a silicate of iron, which in itself is very fusible, but its fluidity is greatly diminished by the presence of several fragments of quartz and quartzose rock entangled with it. It is too viscid to flow out spontaneously, but must be got out by a rake. To prevent it as much as possible from mixing with the matt, the sole *s* of the furnace is so arranged as to incline towards a sort of basin, *h*, Fig. 617, on one side of the furnace, and occupying scarcely ⅓d of the area of the sole. At the end of the operation, the scoria covers the matt only in this basin, in all the other parts it rests on the sole. The scoria nevertheless contains a considerable portion of copper, and it is for the purpose of recovering this copper that the scoria is cast into bricks. The granulated copper having a tendency to fall to the bottom of the mass of slag, it is chiefly collected in the mould, No. 1; the 3 other moulds being supplied by the overflowing of No. 1, contain a very much less quantity of copper. The men mark the bricks of slag in the order in which they were cast. The scoriæ are at a white heat when they are cast, and their temperature is kept up as long as possible, to facilitate the subsidence of the copper; hence, during the casting, iron plates are set up on edge near the moulds to keep off the cool air, and when the casting is complete, the bricks are covered over with sand, In the meantime, the matt continues to flow, its surface in the furnace being protected by the coating of slag, a portion of which has not been disturbed. A certain portion of slag is also left on the sole to protect it from the corrosive action of the slags formed by the next charge, which is introduced while the matt is still flowing off. The volume of fluid matt produced by each charge does not exceed 12 gallons, and the yield of two contiguous furnaces, (Nos. 2, Fig. 620,) is collected into one pit.

With new varieties of ore, the work is a little more laborious, and requires the supervision of the inspector of the foundry; or should the supply of certain ores which are usually employed, fail, the proportions of the charge require modification. In such cases, the flux is not added to the charge at once, and many successive rabblings are required to ascertain the progress of the fusion, the flux is then added as occasion requires. In this way, much practical knowledge is gained which contributes greatly to the success of the work.

The metallurgic re-actions in Op. II. are simple. The oxides and sulphurets are combined in the charge in such proportions that the oxygen lost by the oxides whose metals pass into the matt, and the oxygen lost by the ferric oxide which passes in the shape of ferrous oxide into the scoria, combine with the sulphur of the sulphurets, and form sulphurous acid, the disengagement of which keeps up a certain agitation which favours greatly the progress of the re-actions. The action of the fluoride of calcium, or fluor spar, is somewhat complex. In the gangue of the copper ores alumina and magnesia are more common than lime; the portion of calcium, which, under the influence of oxygen and silica, passes into the state of lime, contributes to the fluidity of the silicates. About one half of the fluor spar remains undecomposed, and the fluor silicate which is formed, adds to the fluidity of the scoria. The fluoride of calcium, which is at first dissolved rapidly in the silicates, for which it has a great affinity, is then decomposed gradually under the influence of the fragments of silica suspended in the mass; the silica yields oxygen to the calcium, and the resulting silicum, which is the exact equivalent of the fluorine of the fluor spar, combines therewith. This disengagement of fluoride of silicum forms a sort of natural rabbling of the charge at the period when sulphurous acid is no longer disengaged, and this mechanical action is one of the essential advantages of the fluor spar flux.

The following statement will show the results of Op. II:—

Substances Employed.	
Calcined ore	0.724
Crude ore	0.084
Poor scoria, from Op. IV.	0.085
" " V.	0.051
" " VII.	0.008
Fluoride of calcium	0.041
Earthy matters:—sand	0.001
" " brick	0.006
	1.000

Products.	
Coarse metal, for Op. III.	0.275
Scoria	0.650
Furnace waste, from Op. IV.	0.009
Sulphurous acid	0.055
Sublimed sulphur	0.001
Fluoride of silicium	0.008
Water and carbonic acid	0.002
	1.000

An examination of the scoria produced in Op. II. will always show whether the metal calciner men have done their duty. The scoria are inspected in a court-yard, *y y*, Fig. 620, where the men deposit it in regular order, under the number of each furnace. Each brick is broken with a hammer, and the fracture examined; the lower part of the brick is minutely inspected, especially that of the brick No. 1: the small grains of matt, mechanically mixed with the slag, exhibit a clear bronze colour, and a metallic lustre on the black, dull surface of the fracture. The value of the copper in the slags is thus judged of very accurately: if the proportion be from $\frac{3}{1000}$ to $\frac{12}{1000}$ an experienced eye can tell within $\frac{1}{1000}$ or $\frac{2}{1000}$ the quantity of copper contained therein. In breaking up the bricks the inspector forms the fragments into two heaps; the larger heap contains those which are to be thrown upon the rubbish heap, *r*, Fig. 620, the other heap contains those fragments which are to be returned to the furnace. Each new charge contains 0.071 tons of this rich scoria; a larger proportion than this would be injurious, but as a larger quantity than can be used is produced, the surplus is melted down once a-week or fortnight, for which service the men receive no pay.

The iron cylinder containing the *coarse metal*, as it is called, produced by two contiguous furnaces, is hauled up by means of a crane, Fig. 618, and conveyed in wheelbarrows to the dépôt, Fig. 620.

Sunday is to the men engaged in Op. I. and II., what it ought to be to every one, a day of rest from worldly occupation. The fires, however, require to be kept up, and this service is performed by one man, who has the charge of 4 furnaces, and he must so arrange that the furnaces be at the full heat for the reception of the charges on Monday morning at 5 o'clock.

Third Operation.—The coarse metal obtained in the last operation is in very small fragments, externally of a deep brown colour; they are easily crushed by a blow, and the surface of the fracture is of a brownish red. The metallic copper forms about $\frac{1}{3}$d of the total weight; it is, in fact, very similar to copper pyrites free from gangue. It is, therefore, in the first part of Op. III. simply calcined with access of atmospheric air. The charge is weighed out, and conveyed in wheelbarrows to the hoppers over the calcining furnaces, which are similar to those used in Op. I. Each of these is served by two men, who relieve each other alternately. One man must work on Sunday, because each operation extends over a period of 36 hours.

The most important part of this operation consists in the management of the fire; it is the same in principle as in Op. I., but more fuel is consumed, and the heat requires to be greatly increased towards the end of the operation; 0.043 tons of coal per hour is burnt, whereas in Op. I. it was only 0.035 tons. The charge having been spread over the sole, the temperature is kept up to the highest that it will bear without fusing. Two hours after the doors have been closed it emits abundant fumes of sulphurous acid, and it is rabbled every two hours in order to expose a fresh surface. The charge must be gradually raised during the first 12 hours to an incipient red heat; by the 24th hour the charge and the walls of the furnace must be at a cherry-red heat, and by the 36th hour at a lively red. The effect of rabbling is not only to expose new surfaces, but also to break up any masses which tend to agglutinate.

The coarse metal is the only solid product of this operation; the sulphur passes off in the form of sulphurous and sulphuric acids, while a proportion of oxygen combines with the matt nearly equal to that of the sulphur expelled. Omitting the sulphuric acid, the following tables will show the difference between the substances before and after the operation:—

Substances Employed.	
Coarse metal	0.804
Oxygen of the atmosphere	0.196
	1.000

Products.		
Calcined coarse metal, for Op. IV.	0.536	0.783
" " " V.	0.247	
Sulphurous acid		0.217
		1.000

The product of this operation may be bad either from the result of too high or too low a temperature. There is not much chance of too high a temperature being produced, for this would agglutinate the charge, and give the workman much extra labour in rabbling. The danger is the other way, and in order to keep the men to their work 4 inspectors are appointed to 15 furnaces, whose duty it is to see that the heat is gradually and properly raised, and that the rabblings are attended to every two hours.

The physical and chemical properties of the coarse metal are greatly altered by calcination: the fragments are much reduced in size, the general colour is a deep black, with light brown reflections; many of the grains are friable; others are encased in a friable envelope, the nucleus being hard and compact; this, when broken, has a lustre of various colours; other fragments are formed by the incipient fusion of several particles together.

Fourth Operation.—*White metal*, the object of this operation, is produced by associating with the calcined coarse metal those ores of copper which are almost entirely free from sulphuret of iron, and consist

principally of sulphuret of copper, oxide of copper, and quartz, in such proportions that the sulphuret of iron becomes oxidized at the expense of the oxygen of the oxides. The excess of sulphur, or that which is not acidified in this operation, combines with the whole of the copper, forming white metal, (which, in its purest state, is the disulphuret Cu_2 S,) while the oxide of iron, combined with silica, passes entirely into the slag. In practice, however, these reactions cannot be accomplished with the precision which theory indicates, because it is impossible to bring the oxides and the sulphurets together in true chemical proportions. The reaction is made as complete as possible by prolonging the operation, and the most advantageous result is found to be obtained by leaving a certain portion of iron in the matt, and a considerable portion of oxide of copper in the slag. This enriching of the slag does not produce any inconvenience, for none of it is thrown away, as in Op. II.; on the contrary, it is of considerable value in a subsequent operation. By continuing to enrich the slag the last traces of sulphuret of iron are expelled, and pure white metal is produced. There is, however, danger of exceeding this limit, in which case the oxides in excess act on the sulphuret of copper, and reduce a portion of it; the metallic copper produced under these circumstances is always of inferior quality. Indeed, the principle of the operation of melting for white metal is to avoid as much as possible this reduction of copper, and to attain this end there must usually be left from 4 to 8 per cent. of iron in the matt, and from 3 to 5 per cent. of copper in the slag.

The materials employed in this operation are rather numerous. The calcined coarse metal forms one half the charge: then a proportion of rich foreign ore in the crude state: slags from Op. IX. and X., composed essentially of silica and oxide of copper: furnace waste from all the operations: different copper wastes from the workers in copper, such as scales produced during the lamination of copper: lastly, silica, &c. from the sole and walls of the furnace in which the operation is conducted.

The furnace employed in this operation, No. 4, is similar to that used in Op. II. Fig. 617, but there is no depression in the sole; its whole surface slopes very gradually, just sufficient to allow the escape of all the fused substances towards the orifice of the discharge-pipe, situated on one of the long sides, as at *o*, Fig. 617.

The men entrusted with the charge of the furnace belong to a superior class: they are expected to watch the process narrowly, and to vary the succeeding charge according to the indications of the preceding one; there is no means of exercising a complete control over them, on account of the variable nature of the charge, and especially of the rich foreign ores. The fire is managed as in Op. II. only more coal is burnt. The charge remains six hours in the furnace, and is raised to the most dazzling white heat. The charge weighs ordinarily about 1.6 ton; but this varies; the object being to associate, in proportions as constant as possible, the copper and the sulphur, which after the mutual reaction of the sulphurets and oxides ought to form essentially the matt, and the silica and the oxide of iron, which ought to form the scoria.

The calcined ore, the rich foreign ores, copper scales, &c., are introduced through the hopper and then spread over the sole; the remaining portion of the charge is introduced through the door, and distributed by means of a tool made like a baker's peel. The doors are then carefully luted; the substances calcine rapidly at the surface without entering into fusion: in an hour's time there is a softening, which is made evident by the escaping gases: in 3 hours, a portion of the charge is floating in another portion which has become fused: the surface is not disturbed by the escape of gas. At the 4th hour the masses are detached from the sides and broken up by rabbling. At this time the scoria is very fluid, and on urging the heat all the matters appear in complete fusion and the surface is tranquil. Thus, the first three hours of the operation the fusion of the charge is going on, and during the last three hours the refining of the matt; but during both periods a portion of the more infusible matters are fusing and refining. About 10 minutes before the expiration of the 6 hours, the man pierces the hardened sand at the side of the furnace; the liquid matt flows out and is granulated by being received into water, or cast into pigs by being received into sand moulds: the scoria then flows out in a very fluid state and is also moulded. This scoria contains a considerable portion of copper: it is sorted into two lots of unequal value; the richest portion is that which was in contact with the matt, where oxide of copper prevails; the poorer part consists of the upper layers, where sulphur prevails: the former are treated in a special operation, No. VI; the latter are useful in Op. II. in which they act as a flux, and give up all their copper to the coarse metal.

The following tables will show the results of this operation:—

Substances Employed.

Calcined coarse metal, Op. III	0.559
Crude ores	0.243
Copper scale, &c.	0.007
Scoria from roasting, Op. IX	0.060
„ „ refining, Op. X.	0.024
Furnace waste, Op. II. and IV. to X.	0.060
Earthy matters:—sand	0.041
„ „ bricks	0.006
	1.000

Products.

White metal, for Op. IX.	0.402
Poor scoria, for Op. II.	0.261
Rich ditto, for Op. VI.	0.281
Furnace waste, for Op. IV.	0.009
Sulphurous acid	0.043
Water and carbonic acid	0.004
	1.000

The white metal is conveyed to the furnace for Op. IX: the scoria is removed to the dépôts *y*, *y*, Fig. 620, where it is broken up. Each furnace elaborates 22 charges per week.

The white metal in its purest form has a very clear greyish white colour: it has a granulated texture, and is full of numerous small cavities: its sp. gr. is

5.70. Another form of this metal has a bluish or black grey colour, with violet and reddish reflexions: its sp. gr. is 5.32. The usual product is something intermediate between these two varieties, and consists, in 1,000 parts, of copper 0.732, iron 0.063, and sulphur 0.205. It is, in fact, nearly identical with the sulphuret of copper of the mineralogists.

Fifth Operation.—This operation is in many respects analogous to No. IV., its object as well as that of Op. VII. and VIII. being the production of a matt of a richer and purer quality than is usually produced by Op. IV.

It has been found by experience, that when native and foreign ores are subjected to the same treatment, a copper is produced either of medium quality or distinguished by certain good or bad properties. The ores which yield a superior copper are generally worked alone, expressly for Op. V.: the ores of ordinary value pass through the first four operations already described; and the ores of very inferior quality are kept quite distinct, and are worked in furnaces appropriated to the purpose. From the combination of the products of these ores, and from the blending of richer and poorer ores at certain stages, the different varieties of copper known in commerce are produced. The calcined coarse metal used in Op. V. is sometimes that which has been produced from picked ores; at other times it is identical with that ordinarily used in Op. IV.; but in all cases a certain proportion of calcined ore is used as produced from the best copper pyrites. No crude ore is added to the charge, nor is any flux given except that which arises from the sole and walls of the furnace in which the operation is conducted. The following statement will show the nature of the charge and the results of the operation:—

Substances Employed.

Calcined coarse metal, Op. III.	0.722
Calcined ore	0.185
Earthy matters:—sand	0.084
" " bricks	0.009
	1.000

Products.

Blue metal, for Op. VII.	0.495
Scoria, for Op. II.	0.434
Furnace waste, for Op. IV.	0.008
Sulphurous acid	0.056
Oxygen	0.007
	1.000

The charge in Op. V. is richer in metallic sulphurets, and contains fewer metallic oxides, than in the charge for Op. IV., so that the result of Op. V. is a matt more charged with sulphur and iron than the ordinary white metal. Blue metal is distinguished by a fresh fracture, a deep grey colour, but at temperatures below redness it assumes beautiful shades of blue, which give a name to the metal. It is more compact than white metal, but its cavities are larger.

The reactions are similar to those of Op. IV. The first action of the heat is to fuse the sulphurets, and to produce a partial reaction on the oxides. The oxide of copper reacts by its oxygen on the sulphur, and on the iron of the sulphurets, producing sulphurous acid, which is disengaged, and ferrous oxide which combines with the silica. The copper thus set free unites with the matt, which is thus doubly enriched by the addition of copper and the removal of sulphuret of iron. While this reaction is going on in substances which are very refractory, a silicate more or less charged with oxide of copper, begins in its turn to liquify and to perform its useful office of refining the matt; the oxide of copper of the silicate and the sulphuret of iron of the matt, mutually react upon each other, and produce, without any disengagement of gas, sulphuret of copper, which enriches the matt, and peroxide of iron ($Fe_2 O_3$) which passes into the scoria.

Metallic copper, which is only accidental in white metal, is characteristic of blue metal. It is disseminated through the compact mass in exceedingly fine particles, which are visible with the assistance of a lens, and there are also occasionally larger particles visible to the unassisted eye. Silky iridescent filaments are also sometimes produced. If the charge has not been properly selected or well managed, there forms below the matt, and at its expense, a certain quantity of black copper, called from its position *bottoms:* this will be noticed again.

Sixth Operation.—The copper produced by the remelting of the slags, formed in Op. IV. VII. and VIII. is of excellent quality, and is known in commerce as *best-selected.* The object of this operation is to make this copper pass into the matt, which is always richer than the blue metal of Op. V.; this object is effected by the mutual reaction of the oxide of copper of the slags, and of certain very pure sulphurets of copper and of iron existing in certain varieties of ore. The reaction is assisted by the addition of small coal to the charge, which effects the reduction of a portion of the oxide of copper, and the metallic copper thus revived traverses the scoria and the matt, and forms into two distinct layers, the lower one consisting of a very impure black copper or *bottoms*, the upper of a white alloy of copper and tin, called *hard metal.*

The charge usually consists of an ore (copper pyrites) free from injurious substances, abounding in quartz, but too poor for Op. V., after being calcined. The exclusion of substances containing sulphur is more attended to than in Op. IV. and V., and hence the sole of the furnace is more exposed to corrosion, especially at the edges of the sole near the walls. This is partially remedied by heaping the charge around the circumference of the sole, which is thus better protected, and when the sulphurets have fused, the quartz of the ore furnishes to the scoria the silica, which would otherwise be taken up from the sole. The furnace is similar to that used in the previous operation, but the external arrangements are different; there is no hopper, but the charge is inserted through an opening on one of the long sides, either by means of the peel or by hand. This opening is closed, and the door luted during the working.

The following tables will show the nature of the operation:—

Substances Employed.	
Rich slag, from Op. IV.	0.671
" " VII.	0.095
" " VIII.	0.053
Copper pyrites	0.079
Sweepings of the foundries, Ops. VIII. IX. X.	0.055
Carbon, employed as reagent	0.001
Earthy matters:—sand	0.036
" " brick	0.010
	1.000

Products.	
White Metal, for Op. VIII.	0.057
Red metal, for Op. VIII	0.016
Tin alloy	0.005
Coppery bases, for Op. IX	0.008
Slag, to be rejected	0.901
Refuse of furnace, for Op. IV.	0.006
Carbonic acid	0.003
Gasefied sulphur	0.003
Water and carbonic acid of the ore	0.001
	1.000

The white metal thus produced is similar to that of Op. IV., the red metal resembles the blue of Op. V. but differs in the absence of metallic copper; it is also richer in copper and more compact. The alloy of copper and tin (*hard metal*) is hard and brittle, and of a fine tin white colour. It contains minute portions of iron, nickel, cobalt, arsenic, and a trace of sulphur. It is sold to the manufacturers of copper sheathing, its chief use being for the bronze nails used in fixing sheathing.

In Op. VI., the principle is first to reduce the oxide of copper combined with the slags, and to make it pass into the matt, by the double influence of a large quantity of sulphuret of iron, combined with the matt as in Op. IV. and V., and of a trace of sulphuret of iron combined with the silica of the slag as in Op. II., and in the second place, to refine the matt produced, by removing from it, by the influence of the metallic copper and tin, substances which are particularly injurious to the quality of the copper, such as arsenic, nickel, and cobalt. The metals disengaged from the silica, and placed beyond the action of the sulphurets, absorb these injurious substances, which would otherwise have remained in the matt. The metals thus reduced by the direct action of carbon on the oxides of the silicates cannot combine with the matt, for in this, the iron and the copper are saturated with sulphur. The addition of carbon, therefore, produces a quantity of copper and of tin in a minutely divided state, which passes through the matt and collects at the bottom. This action has also a beneficial influence in purifying the matt; the sulphurets of arsenic, nickel, and cobalt, having a strong tendency to yield their bases to the copper and tin, and their sulphur to the elements of the matt, decompose slowly under this influence, and form alloys, which fall to the bottom, and according to the period of the operation produce either sulphuret of copper, which remains in the matt, or sulphuret of iron, which combines partly with the silicates of the slag.

Seventh Operation.—The object of this operation is to convert the blue metal into white metal, and to expel more completely the substances which interfere with the purity of the copper. This is accomplished by two successive reactions,—1, A slow calcination at a moderate heat, in which, under the direct influence of the air, the principal part of those substances which injure the copper, and a large proportion of the copper itself, are oxidised; 2, fusion, at a high temperature, in which the oxides having been scorified by means of silica, that portion of the matt which was not decomposed during the first period, is refined by the reaction of the oxide in the scoria upon the sulphuret of iron in the matt. This reaction is similar to that which takes place in the second periods of Op. IV. and V.; but the reaction of the oxygen in the first part of the process is distinct from any that has yet been considered.

Blue metal is the only form of copper used in this operation, but its surface is impregnated with sand obtained in casting, which is of use in the process, as is also the furnace waste and the refractory clay introduced every now and then to lessen the corrosive action of the slag; this sand, brick-dust, and clay, reacting on the oxides, produce the scoria necessary to the refining of the matt. 2 tons of blue metal make a charge, and the operation lasts nearly 12 hours. In the first part of the operation, the sole must be cool, so that $\frac{3}{4}$ hour elapse between the drawing of one charge, and the putting in of another. The blue metal must be put in in very large pieces, and as it is very brittle, each piece is put in by means of a peel worked by 4 persons; the operation somewhat resembles that by which the baker fills his oven with bread. The arrangement of the blocks in the furnace is important; none must be nearer than 3 or 4 feet to the bridge, and spaces must be left between them for the free circulation of the gaseous currents.

The two doors by which the charge is inserted being closed and well luted, the register is opened, and the temperature raised quickly to a dull red; the blocks, under the action of the heat and the oxygen of the air, then fuse slowly, and in the course of $8\frac{1}{4}$ hours, the whole of the charge is in a semifluid state. The heat is then urged for the second part of the process, and in about $2\frac{1}{2}$ hours it is complete, and the matt and the scoria are cast in a trench in the sand. The following is the statement of this operation:—

Substances Employed.	
Blue metal, from Op. V.	0.789
Furnace waste, &c.:—sand	0.108
" " clay and brick	0.006
Oxygen of the atmosphere	0.097
	1.000

Products	
White metal for Op. VIII.	0.588
Poor slag, for Op. II.	0.103
Rich slag, for Op. VI.	0.177
Furnace waste, for Op. IV.	0.008
Sulphurous acid	0.124
	1.000

Eighth Operation.—The products of Op. VI. and VII. are further purified by this operation, which consists (1) of calcining the white metal at a low

heat, under the influence of atmospheric oxygen; (2) refining the metal under the slag. But as iron and other extraneous metals exist only in small quantity in the white metal, a comparatively large proportion of oxide of copper is formed during (1), so that in (2) the slag is rich in oxide of copper. Hence the refining due to the mutual action of the metal and of the slag is soon accomplished. The oxide of copper formed in (1) being in excess, reacts on the liquid metal under the higher temperature of (2), whence results sulphurous acid, which is disengaged, and metallic copper; this is precipitated to the bottom and removes from the matt the noxious metals which may be still contained in it. The following statement will show the result of this operation:—

Substances Employed.	
White metal of Op. VII	0.712
Ditto VI.	0.125
Red „ VI.	0.034
Earthy matters from the sole	0.041
„ „ brick and clay	0.007
Oxygen from the atmosphere	0.081
	1.000

Products.	
Regulus of metal VII. for Op. IX.	0.528
„ of metal VI. for ditto	0.112
Coppery bases from VII. for ditto	0.088
Ditto „ VI. ditto	0.020
Slags, to be used again in Op. VI	0.118
Furnace waste, ditto „ IV	0.004
Copper sweepings, for VI.	0.002
Sulphurous acid	0.128
	1.000

This operation furnishes 3 products: 1, a slag; 2, a matt or regulus very rich in copper; 3, bottoms. The slag consists almost entirely of silica, oxide of iron, and copper. It also contains about 0.11 copper of the matt mechanically mixed. The regulus is the sulphuret of copper, mechanically mixed with metallic copper. It is of a fine metallic grey colour; it is porous, with large cavities coated with a very thin pellicle of copper, the lustre of which varies from tin white to intense red with blue shades. The regulus contains copper 0.811, iron 0.002, sulphur 0.185. The copper bottoms are formed in small plates or scales of a clear but dull red colour, and impregnated at the surface with matt and sand.

Ninth Operation.—The complex series of operations thus far described has led to the formation of various products; such as the white metal of Op. IV., the blue metal Op. V., the matt from the remelting of the slags Op. VI., the white metal of Op. VII., the regulus of VIII., the copper bottoms of Op. VIII. and VI. All these products now converge into Op. IX., so that with the exception of the tin alloy, Op. VI., no saleable product has yet been produced. The object is now to expel the sulphur, which up to this period has performed the useful office of a medium, in which to collect, combine, and concentrate the copper as it becomes gradually freed from its other impurities. There is still a minute portion of arsenic, iron, tin, nickel, cobalt, &c. which have resisted the action of Op. IV. to VIII. These are got rid of in the slag. There are two successive reactions in this operation, (1) the direct action of the air on the matt, while at a heat near its fusing point, (2) the reaction of the oxide of copper, formed in great excess on the sulphurets not decomposed. The two products of the operations are coarse copper almost refined, and a slag rich in copper, which is sent to Op. IV.

In this operation there are 4 steps: (1,) calcining, which produces sulphurous acid and oxides; (2,) (3 the reaction of oxide of copper on the sulphurets which have not been decomposed; (4,) the production of metallic copper, which collects at the bottom of the sole, while the oxides in excess unite with the silica into a slag which occupies the upper part of the whole.

The charge varies from 2.75 to 3.75 tons; the only reagents employed are atmospheric oxygen, furnace waste, and the quartz of certain rich ores, added to the charge. The time required for this operation is 24 hours. About an hour is occupied in putting in the charge, which is in large blocks; the temperature is then raised to the proper calcining heat. After this, the charge is fused, and the sulphurets and oxides becoming mingled together, react on each other, and the surface of the mass is agitated by the escape of gas. It is now important to keep up this reaction as long as possible, in order to promote the decomposition of the sulphurets and thus get rid of the sulphur; this is done by diminishing the temperature, and this cooling of the furnace, which constitutes the second part of the process, is effected by opening the furnace door; the temperature then sinks from a lively red to an obscure heat, sufficient for the mutual reaction of the oxides and sulphurets, but not sufficient for the union of the oxides and silica to form slag, the production of which is not desirable. The mechanical mixture of the materials, which is indispensable to the reaction of the semi-fluid matters, is effected in a curious manner. The effect of cooling the furnace is, of course, first felt on the surface of the fused mass: this becomes more and more pasty, until a point is attained when the sulphurous acid gas, escaping from all points, cannot traverse the viscous mass; it is, therefore, imprisoned within it, and, accumulating, forms large swellings and risings, which not only increase the surfaces, but bring the particles into contact much more effectually than would be done by a continual rabbling. The whole mass thus becomes extremely porous, and being a very bad conductor of heat, the temperature is preserved by the crust, and the reactions necessary to the operation do not cease for a single moment. All the workman has to do is to add a little fuel occasionally, and to regulate the draught. At 6 p.m., or 12 hours after the commencement of the operation, the temperature being considerably diminished, the sulphurous acid ceases to be discharged, which is a sure sign that the oxides of copper and the sulphurets no longer react upon each other. It now becomes necessary to raise the heat, and this is the characteristic of the third part of the process. Six hours are occupied in raising the temperature to the

point that it had at the end of the first part of the process. All the doors being closed, the upper crust or scoria now liquefies as gradually as it was formed during (2); and the two reactions which were characteristic of (1,) (2,) are reproduced simultaneously up to a certain point.

At midnight, or 18 hours after the commencement of the operation, the charge contains only a very small proportion of sulphur: all that is now required is to separate the copper from the oxides, which up to this time were mechanically mixed with it, and this is done by scorifying the oxides by means of silica. The heat is, therefore, got up to the highest, in order to combine the oxides and the silica into a slag. Under this great heat the copper becomes completely fluid, and collects at the bottom of the mass, while the slag rises to the surface. At 5.45 A.M. the slag is skimmed off and the copper is cast into pigs in the sand. The men then proceed to a new charge. The results of this operation are shown in the following tables:—

Substances Employed.	
White metal, from Op. IV.	0.577
Regulus, from Op. VIII.	0.171
Copper bottoms, from VI. and VIII.	0.034
Very rich ore	0.035
Earthy matters:—sand	0.016
,, ,, bricks and clay	0.008
Oxygen of the atmosphere	0.159
	1.000

Products.	
Coarse copper, from the white metal	0.433
Ditto from the regulus	0.143
Ditto from bottoms	0.030
Slag, for Op. IV.	0.087
Furnace waste, for Op. IV.	0.007
Copper sweepings, for Op. VI.	0.001
Carbonic acid and water of the ore	0.001
Sulphurous acid	0.298
	1.000

The coarse copper, the chief product of this operation, is run into pigs, each about 3 feet long and 18 inches wide: they are usually impregnated on one face with the sand of the trough; they are full of cavities of various sizes, and the surface appears as if blistered; hence the term *blistered copper* applied to it. The fresh fracture exhibits a deep red colour, and the inner surfaces of the cavities present brown or yellow reflexions.

The scoria differs in appearance from all the previous slags: it contains more silica; it is of a brownish black colour, without metallic lustre; it is full of little cavities, and resists the hammer as much as certain basaltic lavas, which it in some respects resembles. It contains a quantity of copper in fine grains, and here and there some tolerably large fragments.

Tenth Operation.—The object of this operation is to separate all the remaining impurities from the copper, and to impart to it that soft and malleable property which allows of its being worked by the hammer and the rollers. All the coarse copper produced in any of the previous operations now comes into this last one, and the only reagents are atmospheric oxygen, and the waste of the furnace in which the operation is conducted. Towards the end of the operation, however, charcoal and green wood are used. The furnaces employed are of large size, the charge weighing as much as 7 tons, and entirely filling the body of the furnace.

As soon as one charge is disposed of, the furnace is examined, and the parts near the walls and the soles which require it, are stopped with refractory clay; the sole is then raked over, and the charge put in, the pigs being placed one at a time on the peel. All the doors being carefully luted, the man has nothing to do for 18 hours but to attend to the fire, and for this purpose one man has the charge of two fires. Under the influence of the two gases which form the flame, the copper fuses, and a portion becomes oxidized by the in-rushing draught; this oxide reacts either directly, or after having united with the silica, on those substances in the copper which are more oxidisable than the copper itself; and in this way a slag is gradually formed, which contains, in addition to oxide of copper, the oxides of all the metals which were still left in the coarse copper. About 21¾ hours after the commencement of the operation the copper is as free from sulphur, arsenic, &c., as the nature of the metal operated on will allow. The work of the refiner now properly begins, and the charges are regulated so that the copper may be in that state when the refiner and the other people concerned in the operation begin their day's work. The first thing that is now done is to skim off the slag from the surface of the metal. The copper is now in that state which is called *dry;* it is brittle, of a deep red colour, inclining to purple, of an open grain, and crystalline structure. In this state it has a strong action on iron; the tools employed in removing the slag, &c., wear away more rapidly at this time than when the copper is in its malleable state. The copper is made tough or malleable by the action of carbon and combustible matter on the copper during a short period only, for it has been found by experience that the property of malleability is produced after a certain contact with the carbon and the metal, and becomes considerably weakened if prolonged only for a few minutes, and destroyed if the action is continued. It may, however, be restored by leaving the copper exposed to the oxidising influence of the air.

When the bath has been skimmed, 4 or 5 peels-full of charcoal are thrown upon it; the charcoal spreads immediately over the fluid metal, and covers it almost completely. Some very pure Welsh anthracite can generally be used instead of the charcoal, which is only used in refining some of the very best sorts of copper. When the bath is thus covered with carbon, a tolerably stout pole of green wood is plunged into the midst of the metallic mass; the juices of the wood are immediately disengaged in a gaseous and vaporous form, which causes the fluid metal to bubble up, and foam with great violence, an operation which greatly accelerates the effect which the charcoal would produce in the course of time.

During all this time the draught is considerably diminished, and the air which feeds the fire passes up and escapes by an opening above, without entering the furnace; hence the metal, not being cooled by

the air rushing in, retains its high temperature, and the scoria, which had attached itself to the sides of the vault, falls down in drops, and contributes to increase the new layer of scoria which is forming on the surface of the metal. In the meantime the strong effervescence is kept up on the metal from 15 to 25 minutes, until the refiner has detected the exact moment when the metal has attained its maximum of malleability. This is done by making an assay in the following manner:—Having exposed a small portion of the surface of the metal 3 or 4 feet beyond the door, the man introduces an ingot mould attached to the extremity of a long iron rod, and quickly catches up a small portion of copper. This ingot is then cut half through by means of shears, and broken in two by means of a hammer. The surfaces of the cut and of the fracture vary with different varieties of copper, and enable the assayer to judge of the malleability of the specimen in hand. But for any particular variety of copper the character of the fracture may vary in every ingot taken out, and all these differences have an intelligent meaning to the practised eye of the assayer. If the action of the charcoal has not been sufficiently prolonged, the first ingots taken out will exhibit a dull, granular fracture, of a deep brick red colour, with scarcely any metallic lustre. In the succeeding specimens the structure passes insensibly into the fibrous, the fibres being exceedingly minute and of a silky lustre; the colour is also of a pale red, the characteristic of rose copper. Beyond this type the texture becomes coarser, the fibres increase in size, and their fracture exhibits striæ; the lustre, without losing its metallic brilliancy, ceases to be silky; the colour becomes paler, and a yellow shade is very decided. If after this the surface of the bath be left to the action of the oxygen of the air, the characters of the metal change in an inverse order. The two extremes of grainy and fibrous represent coppers which are not adapted to any mechanical processes; but the maximum of malleability corresponds to the most silky texture. This type being attained, the bath is once more skimmed, to remove the charcoal and a thin layer of slag; a little fresh charcoal is then thrown over the surface, a quantity of fuel is thrown upon the fire to produce a quantity of combustible gas, which is admitted into the furnace; and then the casting is proceeded with. The copper is taken out in iron ladles coated with clay, and is poured into moulds adapted to the wants of the manufacturer. The usual size of the cakes for common purposes is 12 by 18 inches. Although a number of men are engaged in the casting, it generally lasts $1\frac{1}{2}$ hour. During this time the copper is kept in as uniform a state as possible, and it is repeatedly watched by taking assays out of the ladles. The charcoal which covers the surface of the bath acts in a manner the reverse of that of the oxygen of the air, and under these opposing influences the metal ought to remain in a state of equilibrium throughout the casting. The assays detect any deterioration either towards the granular or the fibrous structure, and, according as one or other occurs, charcoal is added, or taken away. The following statement shows the result of this operation:—

Materials Employed.	
Coarse copper	0.954
Earthy matters:—sand	0.013
" " brick and clay	0.021
Oxygen of the air	0.012
	1.000
Products.	
Saleable copper	0.908
Slag, for Op. IV.	0.055
Furnace waste, for Op. IV.	0.022
Copper sweepings, for Op. VI.	0.002
Sulphurous acid	0.013
	1.000

The varieties of copper which are sent into the market are produced by varying the ores, the proportions of the charge, and the treatment. Among these varieties the following six may be mentioned, with the prices in 1848:—

		£	s.
First Quality...	*Best selected copper*, from slag of regule	98	0
Second Quality,	*Best selected copper*, from the regule (extra process)	97	5
Third Quality..	*Tough copper*, for exportation. Copper of ordinary manufacture, mixed with one-third of best selected (second quality)	96	0
Fourth Quality,	*Tough copper*. Copper of ordinary manufacture, from common ores	95	2
Fifth Quality...	*Tile copper.* Of ordinary manufacture, from ores loaded with foreign matters	94	0
Sixth Quality..	*Tile copper.* Manufactured from bottoms, Op. VI. and VIII.	93	5

The first two qualities are almost chemically pure copper: they contain the merest trace of those substances which so greatly injure the valuable properties of copper. The other qualities contain about 0.008 of arsenic, nickel and tin, bodies which cling to copper with more pertinacity than any of the other impurities.

The following statement shows the quantity of copper produced in this country during several years:—

	Tons.	£	s.	d.	Standard price. £	s.	d.	Produce
1830	141,263	802,979	9	0	103	2	0	$8\frac{1}{4}$
1836	140,981	957,752	8	6	115	12	0	$8\frac{1}{4}$
1840	147,266	792,758	3	6	108	10	0	$7\frac{1}{2}$
1848	155,616	825,080	2	6	97	7	0	$8\frac{1}{4}$

In 1840 the quantity of ore raised was greater, yet the money produced was less than in 1830: the quality or produce of British ores seems to be deteriorating: it is supposed that as the mines become deeper the ores become poorer.

The total quantity of foreign copper ores imported during the year ending 30th June 1849, amounted to 50,053 tons, and of regulus or ore partly manufactured[1] 124 tons. Of this quantity (35,753 tons of which were sent direct to Swansea,) Cuba contributed 30,679 tons, Chili 4,503, South Australia 7,783, New South Wales 3,688, Van Diemen's Land 543, New Zealand 70, Peru 1,882, China 388, Italy 126, Spain 120, Western Coast of Africa 101 tons. The annual average price of foreign ores for the 4 years ending 1847, was, Chili 23*l.* 6*s.* 3*d.* per ton, Cuba 13*l.* 5*s.* 5*d.*,

(1) In Australia, smelting houses have been erected to smelt the poorer ores that will not pay for being brought to England.

Australia, &c. 17*l.* 17*s.* 3*d.*, and the other countries named 15*l.* 9*s.* 1*d.*

The value of the exports in brass and copper for the year ending 1846, amounted to 1,558,187*l.*, in 1847 to 1,541,868*l.*, in 1848 to 1,272,675*l.*

The following quantities were exported during the year ending 5th January, 1849:—

	Tons.
Unwrought copper in bricks and pigs	4,261
Coin	22
Sheet, nails, &c. including mixed or yellow copper.	8,947
Copper wire	16
Wrought copper of other sorts	219
	13,465

In 1849 the chief places of export were, London 6,502 tons, Liverpool 4,892, and Swansea 1,212.

Of the quantity exported, the United States took 2,618 tons, France 1,682, Holland 684, Hanseatic Towns 674, Belgium 650, the Brazils 635, Foreign West Indies 264, and the British East Indies 3,582.

The number of persons employed at Swansea in smelting copper is about 3,500, exclusive of colliers who raise the fuel. The shipping between Cornwall and Wales amounts to about 20,000 tons, and about 1,200 seamen are employed.

The number of calciners and furnaces at Swansea is about 550; 450,000 tons of coals per annum are consumed: about 3,000*l.* per week are paid in wages. One foundry smelts 47,000 tons of ore every year, producing 6,250 tons of saleable copper.

COPPERAS, or *green vitriol* in its pure state, is protosulphate of iron FeO, SO_3. See IRON.

COPYING MACHINES, machines for multiplying copies of a writing, such as letters and circulars. The first machine of this kind was proposed by Dr. Franklin, who directs the letter to be written with gummed ink and sanded over with emery powder. It is then to be placed on a smooth plate of pewter and passed through a copper-plate printer's rolling press. The impression of the emery is left on the pewter, and printing ink being applied to the plate, an impression may be taken, which is a copy of the letter. It would seem, however, that the multiplication by means of the lithographic press would be as cheap and far more satisfactory in its results. In 1780 Mr. James Watt of Birmingham obtained a patent for copying recent manuscripts. A sheet of thin unsised paper is wetted and then placed between two woollen cloths to absorb the redundant moisture. Being laid on the manuscript, the two are passed together through a rolling or screw press, when the thin paper is found to have received a reverse impression of the letter, legible when read through the transparent substance of the paper. Mr. Watt proposed to wet the thin paper with a solution containing some of the constituents of ink, in order to make the writing more distinct. A better plan, however, is to write the document intended to be copied with a thick ink prepared for the purpose, or to add a little sugar to common writing ink. An improvement on Watt's machine by Mr. Ritchie of Edinburgh is shown in Fig. 621, in which *b* is the bed of the press, *p* the platten, *hh* handles revolving on the screw *s*, which are used to draw down the platten on the paper, &c. placed beneath: the screw works in a square piece of steel, which slides in a hole of similar figure on the head of the press, as shown by the dotted lines, and on the

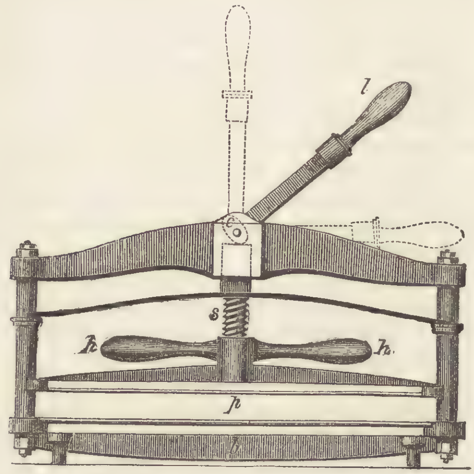


Fig. 621. RITCHIE'S COPYING-MACHINE.

top is a small cam *c* worked by the lever *l*. The pressure is first given by means of the screw, and the cam being afterwards brought down vastly increases the force through a small space. Mr. Ralph Wedgwood obtained two patents for copying machines, the first in 1806, in which he proposes to employ, 1, a sheet of paper, over both sides of which printer's ink is spread: this is allowed to dry during six weeks between leaves of blotting paper; 2, a smooth pewter or copper plate; 3, on the metal plate is laid a leaf of letter paper; over it the blackened paper, and over this a leaf of thin paper previously oiled to increase its transparency; 4, on the paper thus disposed the writing is performed by means of an agate style, ground and polished to a smooth round point: the effect of which is that the letter paper receives an impression from the blackened paper, and this impression is in the right direction, and constitutes the letter which is to be used as the original. The upper oiled paper receives an impression which is inverted, but it may be read in the right direction by looking through the paper. This forms the duplicate or copy. The second patent (1808) was for a certain disposition of two leaves of paper by folding or rolling. The part of the sheet on which a line of the original is written, is brought close to the part of the other sheet on which the corresponding line of the duplicate is written. The line of the original and of the duplicate are formed at the same time by two pens fixed in the socket of one handle, which is held like a pen in the usual way. In Mr. Hawkins's polygraph, two or more pens are carried in a framework, and so connected by joints, that whatever motion is given by the hand to one pen the other pens describe similar figures; so that while a person is employed in writing a letter with one of these pens, the others make copies on separate sheets of

paper. This machine, however, is somewhat complex, and is attended with some practical difficulties.

One of the simplest and probably, therefore, the best copying machines is the invention of Mr. Brunel. The bottom of the press *b*, Fig. 622, is made of gun

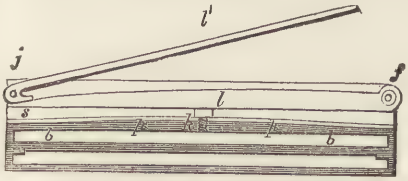


Fig. 622. BRUNEL'S COPYING-MACHINE.

metal; *p* is a pressing board of wood with a steel plate spring *s*, resting on ledges and supporting the pressing board by the screw *k*. A strong steel lever *l* moving on the plane *f*, presses near its centre on the head of the screw *k*; and *l'* is another lever moving on the joint *j*, to which the power of the hand is applied. The letter to be copied is damped by a metallic cylinder with several sheets of fine linen rolled round it, of the same size as the sheets of paper used. It is then put into a transferring book, and a blank leaf of paper is turned over upon it: a sheet of the damp linen is then laid upon the blank leaf, and above that a leaf of oiled paper: the book being shut and introduced between the bottom of the press and the pressing board, the hand is applied to the lever *l'*, which presses down the lever *l* with great force and communicates the pressure to the book by means of the knob *k* of the pressing board, thereby imprinting on the oil-paper a legible copy of the letter, inverted on the side next to it, but easily read on the other side of the transparent sheet.

CORAL. The red coral of commerce, is the axis or inorganic framework of a species of polype, which is found in the Mediterranean and the Red Sea, growing arborescent at the bottom of the water, attached to stones, rocks, fragments of lava, &c. "In its natural state it is covered with a whitish rind, united to the axis by a reticulated membrane abounding with milky follicles: on the surface of the fleshy rind are thinly scattered tubercles with a cavity or cell, in which a milk-white and almost transparent polype is lodged, having the mouth surrounded by 8 conical tentacles. This fleshy rind becomes friable and chalky when dried." Red coral seldom exceeds the height of a foot, which it attains in shallow water in 8 or 10 years. It is of slower growth in deeper water. When full grown, it increases slowly in circumference, and at length the living rind dies, and the axis is attacked by various minute boring animals, which pierce it in all directions and destroy it. Coral grows at various depths, from 6 or 7 fathoms to 60 or 100. Along the French coast it seems to prefer the surface of rocks which incline to the south, and in the Straits of Messina it prefers an eastern aspect. The growth and quality of the coral seems to depend greatly on the influence of light and heat, and the most beautiful is obtained in shallow water. There are 15 varieties of coral distinguished in commerce, according to their degrees of hardness and brilliancy of colour, by such names as *froth of blood*, *flower of blood*, *first*, *second*, *third blood*, &c. The coral from the French coast and the Italian Seas is most esteemed, and the price is said to vary from 8 or 10 guineas an ounce, to less than 1*s.* per pound. On the African shores of the Mediterranean, the colour is less brilliant, and although the branches are thicker, the texture is less compact. Coral is composed of cartilaginous matter, with carbonate and phosphate of lime.

There are coral fisheries in many parts of the Mediterranean. The ground is divided into separate portions, one of which is dragged once every 10 years. The apparatus for dragging it is very rude: it consists of a large cross of wood, with a heavy weight in the centre, and nets properly secured to each limb; this is let down from a boat by means of a rope; the boat is then rowed over the coral beds, and the stems and branches are broken off by the machine, and become entangled in the nets. No doubt a good deal of coral is lost by this clumsy method.

Coral is not so much esteemed as formerly. In the middle ages it was used as a medicine, and the priests of ancient religions offered it to the gods.

CORBEL, a projecting piece of stone, wood, or iron, for supporting a weight of materials. The projecting of one stone beyond another, is called "corbelling out;" this is done both in masonry and brick.

CORDAGE. See Rope.

CORK, the soft elastic bark or *cortex* (whence the word *cork*) of a kind of oak, (*Quercus suber*) inhabiting Spain and Portugal. "The bark of all trees consists of a parenchymatous or soft cellular substance, and of a harder ligneous tubular tissue; in most species, the latter is most abundant; in the cork, the former constitutes the mass of the bark, and hence its elasticity and the facility with which it is cut in all directions. When however it is first generated, the bark of the cork-tree is far less elastic than it becomes subsequently, which is owing to its consisting, in the first instance, of a large proportion of woody matter. When the latter is once formed, which takes place in the first year of its growth, it never increases, however long the bark may remain in the living state; but the parenchymatous substance will go on growing as long as the bark is alive, a provision of nature connected with the annual increase in diameter of wood, and the necessity of the bark giving way to the pressure from within. If the growth of the parenchyma is prolonged and rapid, a corky substance is the necessary consequence, as in certain kinds of elms, the common oak itself, and many other trees; but it does not occur in any European tree in such excess as in the cork. As soon as the bark dies, it of course ceases to grow, and then, not distending as it is pressed upon from within, it falls off in flakes which correspond to the layers that are formed annually. These flakes are the layers of cork, which the Spaniards collect under the

name of the outer bark, while the inner living bark is or rather should be spared."[1] The cork-tree is most abundant in Catalonia and Valencia, whence the principal exports have been made. The cork is removed from the trees in July and August, for which purpose the bark is cleft longitudinally at certain intervals down to the crown of the root with an axe, the handle of which terminates in a wedge: a horizontal incision is then made round the tree from each extremity of the longitudinal cuts. The bark is then beaten to detach it from the liber, and the wedge-shaped handle being introduced, it is raised up and thus removed. The tree is about 15 years old when this operation is first performed; the first crop is not of much value, and the second, which is removed about 10 years after, is not very valuable. After this, the operation is repeated every 8 or 10 years, and the produce improves both as to quantity and quality at each operation. A tree thus barked will, it is said, live 150 years. After the pieces are detached, they are soaked in water, and when nearly dry, are placed over a fire of coals, which blackens their external surface, makes them smooth, and conceals the smaller blemishes; the larger holes and cracks are in some cases filled up with soot and dirt. The pieces are next loaded with weights to make them flat, and are afterwards dried and stacked, or packed up in bales for exportation. Unmanufactured cork is admitted into Great Britain free of duty; the import duty on corks ready made is 8*d.* per lb. Corks squared for rounding, pay 16*s.* per cwt., and fishermen's corks, 2*s.* per cwt. The quantity entered for home consumption amounts on an average to from 40,000 to 50,000 cwt. Its price varies with its quality, from 17*l.* to 60*l.* per ton.

The uses of cork are very numerous, and too well known to require description. Its elasticity renders it very valuable for stopping vessels of various kinds, in order to prevent the liquor from running out or the external air from passing in. The business of the cork-cutter may be thus briefly noticed:—The cork, after being pressed into square pieces, is received by the cork-cutters, and if not sufficiently flat for their purpose, they *lay* it again over a fire in their "burning yard," turning the convex part to the flame; the heat, by twisting the edges of the bark, counteracts the natural bend and flattens it out. During this operation, attention is paid to smoothing it, and covering its defects. It is next cut into slips, by means of a gauge, Fig. 623, set narrow or wide, according to the size of the intended *cork*, *bung*, or *tap*, as the varieties are called, the last being used for stopping the tap-holes of barrels. These slips are again cut into squares of the required length. This operation is performed by one man, from whom they are handed forward to several others. The corks are further divided according to their lengths into *short*, *long*, and *full long*.

Fig. 623.

The cork-maker Fig. 625, is seated before the table or plank, on which is fasted a board Fig. 624, about 3 inches thick, 4 broad, and 12 long; immediately on a line with his left hand, is a piece of wood rising about 4 inches from the board, and fixed about the middle, on which the cork is laid after being cut as above. This wood not only supports the cork, and serves as a guide to the workman, but by its elevation above the board gives room for the knife to cut a part of the cork in a smooth and circular manner, without striking on the table below. The piece is then turned to the point where the last cut ended, and this is continued until the knife has gone completely round; the top and bottom are then pared level, and the cork is thrown into a box or basket with the others of the same length. As the bark is not of the same quality throughout each piece, the corks are sorted into *superfine*, *fine*, *common*, and *coarse*.

Fig. 624.

Fig 625.

The cork-cutter's knife, Fig. 626, is a very thin and sharp blade, about 6 inches long, and tapering off from the handle to the point, as shown in the figure. This knife is sharpened upon the board where the guard is placed, by one whet or stroke on each side after every cut, and occasionally with a common whet stone.

Fig. 626.

The chief art in cork-cutting, is to obtain a regular round and quick turn of the wrist in guiding the knife, so as to complete a tolerably accurate circle, and to make a smooth surface; on which account the knife must be very sharp to enable the men to turn it with ease.

The parings of cork are used for burning into Spanish black.

(1) Penny Cyclopædia article *Cork*.

COTTON. The progress of the cotton manufacture in this country is one of the marvels of the age; and the vast amount of the capital and labour now employed in it leads us naturally to rank the cotton plant among the most valuable and important vegetable substances with which the earth is bountifully furnished. To appreciate in some degree its importance to this country, it is only necessary to bear in mind that the declared value of our exports in cotton goods amounted in 1849 to nearly twenty-seven millions of pounds sterling, while the quantity retained for home consumption was supposed to exceed ten millions. This is a great contrast to the state of things in 1760, when the total value of all the cotton goods manufactured in Great Britain was only about two hundred thousand pounds. At that period, and for thirty years afterwards, North America did not supply us with a single bale of cotton; and there seemed very little prospect of our being in a condition to produce cotton goods that might compete with the fabrics of China and Hindustan, which had long been celebrated for their lightness and delicacy. That we should receive raw cotton from the East Indies, and return it to that country manufactured more dexterously than the celebrated native fabrics, would naturally have been looked upon by us and by the Hindoos as an impossibility. Yet, thanks to British skill and industry, and to the practical spirit of inquiry, which resulted in the invention of the steam-engine and of the spinning jenny, we are now in a condition not only to do this, but to import cotton largely from other quarters, and to surpass the whole world in the extent, beauty, and variety of our manufactures in that material. Of this all the nations of the earth are witnesses, for there is scarcely any part of the globe to which our commerce has not penetrated, and to which our printed cotton goods have not been conveyed. In the factories of Manchester, provision is made for the wants of the inhabitants of various climates, and for races uncivilized as well as civilized. The cotton dress of the African chief, or of the Chinese citizen, is there supplied, in common with the working dresses of our mechanics and their families, or the delicate muslin robes of royalty; and all this variety and extent of manufacturing skill, with its consequent vast amount of good to our labouring classes, is employed on a substance not indigenous to our own country, nor confined to our own colonies, but obtained from other nations with whom we hold friendly relations. This is a powerful argument in favour of free and unrestricted intercourse among the nations of the earth, by which an interchange of productions enables them effectually and thus extensively to help one another, to their mutual good.

More than four-fifths of the cotton at present brought into Great Britain is from the southern part of the United States of America, where the cultivation of the plant is carried on to such an extent that it is reckoned that the labourers and helpers, together with owners, overseers, and their families, dependent on the crop, amount to a million of persons. The cotton now produced in the United States exceeds the production of the whole world in 1770; and this is to be attributed in some degree to the good quality of American cotton, the low price of land, and the improvements introduced into the various processes, but more than all, perhaps, to the energy and skill of the American planters, and the enterprising character of the nation. The cotton-plant (*Gossypium herbaceum*) which thus flourishes in that country, and in other warm climates, as India, China, &c., is a member of the order Malvaceæ, which contains our common mallow; nor is the plant much unlike the mallow, as our illustration will show. The same herbaceous

Fig. 627. HERBACEOUS COTTON.
(*Gossypium herbaceum.*)

character, the same structure of the blossom, which in some varieties is purplish, like the mallow, is in others of a pale yellow colour. But there is a very different appearance of the seed-vessel, inasmuch as from the surface of the seed-coat in the cotton-plant there springs up a thick growth of vegetable hairs, or filaments of considerable length, filling the seed-pod, and at length bursting it, and exhibiting a ball of snowy-white or yellowish down, consisting of three locks, one for each cell, enclosing and firmly adhering to the seeds, which resemble grapes in size and shape.

There are many varieties of gossypium yielding cotton fit for the manufacture, and these have been divided into herbaceous, shrub, and tree cotton; the herbaceous being the most valuable. The above description refers to it; and the crop is described as a very beautiful one when the pods are progressively opening, the fine dark green of the leaf contrasting with the brilliant white of the cotton suspended from the pods, and floating to and fro at the bidding of the wind. This crop is annual; but shrub cotton, though annual in some cool climates, in others lasts two or three years, and in some cases from six to ten. The shrub is about the size of our currant-bush, and in the hottest countries it becomes perennial, and fur-

nishes two crops in a year. Tree cotton is so called because it often attains a height of from twelve to twenty feet. But it must be carefully distinguished

Fig. 628. TREE COTTON. (*Gossypium arboreum.*)

from the cotton-trees of the West Indies and of the American forests. These are prodigious trees, of quite another family, (*Bombax*,) with buttresses projecting from their huge trunks, and more remarkable for their noble aspect than for any useful purpose to which they can be applied. Many of them bear indeed clusters of a woolly substance enveloping the seeds and resembling true cotton; but there does not exist the same adhesion between the hairs, and the cotton of the Bombax cannot therefore be manufactured.

The true cotton-plants are cultivated on a light sandy soil, and in situations where other plants rarely flourish, namely, in the vicinity of the sea, and in what is generally considered very bad land. The saline breezes evidently favour its growth, and the American *sea-island* cotton, which is cultivated on the low sandy islands from Charlestown to Savannah, has long been celebrated for its long fibre, and its strong and silky texture. The cultivators of Georgia and the neighbouring states grow three varieties of herbaceous cotton; the first, from its yellow colour called *nankin* cotton, the second *green-seed* cotton, the third *sea-island* cotton. The first two grow in the midland and upland districts: hence a fine white variety is known as *upland cotton*, or, from a method of cleaning it, *bowed Georgia cotton*. There are also other technical names in use in the trade.

The cultivation of the crop is carried on with great care and attention in the United States. The seed is sown by hand in March, April, and May, in rows five feet apart, each row having its seeds planted in holes eighteen inches asunder, and with several seeds in each hole. The land is kept well weeded, and when the plants come up, the weakest are drawn out, leaving two or three strong plants in each hole. A few months later, they are again thinned, and *topped* to the extent of an inch or two. This checks the upward growth, and promotes the development of side branches. When the cotton is ripe, a number of women and young people go into the field with baskets or bags suspended from their shoulders, to pull the cotton. That which is sufficiently ripe can be gathered with the seeds, without the outer husk, which is the best way; for if the whole pod is gathered, the husk breaks into small pieces, and once mixed with the cotton, cannot be easily separated from it. This crop is liable to damage from wet seasons, which cause diseases called *blast* and *gangrene;* and also from insect enemies, the chief of which are the *cotton bug*, and the *chenille*, or *cotton caterpillar*.

When a good store of cotton has been gathered in and dried, the next task is to separate the seeds from the wool. If this is done by hand, a man can scarcely clean more than a pound of cotton in a day. A rude hand-mill, or roller-gin is therefore substituted in some parts of India and China, by which from forty to sixty-five pounds can be cleaned in a day. After this, the cotton is further cleared from dirt and knots by *bowing*. A large bow being placed in a heap of cotton, the string is made to vibrate powerfully, and this disperses and cleanses the heap. These means employed from remote times in Asia, were also formerly used in America; hence the term *bowed Georgia cotton*. The sea-island cotton is still separated from its seeds by rollers constructed on a large scale, and worked by horses, steam, or water. These rollers are of wood, and revolve rapidly in contact with each other; as they do so, a sort of comb with iron teeth acts on the cotton as it passes between them, and detaches the seeds, which fly off like sparks in all directions. Particles of seeds which escape and pass through with the cotton, are removed by hand. This is called *moting*. The cotton is then whisked about in a light wheel, and when well winnowed, it is conveyed to the packing house, and forced into bags by means of screws, until each bag contains from 300 lbs. to 350 lbs. Short-stapled cotton cannot be properly cleaned by this process. The seeds are so firmly attached to the wool, that a more powerful machine called the *saw-gin*, invented by Eli Whitney of Massachusetts, is put in requisition, and will clean 3 cwt. in a day. The cotton is put into a long and narrow hopper, one side of

which is formed by a grating of strong parallel wires, $\frac{1}{8}$th of an inch apart. Close to the hopper is a roller set with circular saws, an inch and a half apart. These, as they revolve, pass within the grating of the hopper to a certain depth, and seize by their teeth on the locks of cotton, dragging them through the wires, which are not wide enough apart to allow the seeds to pass also. The cotton is afterwards swept from the saws by a revolving cylindrical brush. Thus the separation is effected in a cheap and easy manner, but not without some injury to the fibre of the cotton. All the North American cotton, except the sea-island, is subjected to this process, and since the saw-gin came into operation in 1793, there is nothing in the history of industry to compare with the increase of the American trade in cotton, unless it be our own progress in the manufacture of the same article. In 1792, the total exports of cotton from the United States to various parts of the world, amounted to 138,328 lbs. only. In 1844, the cotton sent from the United States to Great Britain *alone,* amounted to 517,218,622 lbs. At the present time, the supply is not equal to the demand, and should the American cotton crop fail from any cause, great injury would be inflicted on our trade, our mills and machinery would stand idle, and our operatives be deprived of bread. Hence our great manufacturers are looking anxiously to our own colonies in Hindustan, Australia, the West Indies, &c., for a supply, and are urging upon the Government the necesity for promoting the cultivation of cotton by every proper encouragement.

While wool and linen are abundantly alluded to by ancient writers, both sacred and profane, we find few among the latter, and not one among the former referring to cotton. Its growth and manufacture appear to have been quite unknown to the Egyptians, for no specimen of cotton has ever been found among their mummy-cloths, or painted on their tombs, while flax is accurately represented thereon. But while the linen manufacture alone occupied the ancient Egyptians, there is every reason to believe that at the same early period, cotton was manufactured in India. Herodotus, 445 years before Christ, said that the Indians were accustomed to make their clothes of a sort of *wool,* which grew on plants, and was finer and of better quality than that of sheep. Strabo on the authority of Nearchus, likewise speaks of the Indians as being celebrated for flowered cottons or chintzes, and for their various and beautiful dyes. The calicoes, muslins, and other cottons, both plain and ornamented, were among the exports from India in the time of Arrian, who lived in the first or second century. The muslins of Bengal had then attained their celebrity, and were called by the Greeks *Gangitiki,* to denote that they were made on the borders of the Ganges. The Indian fabrics gradually came into use in Arabia and the neighbouring countries, and were diffused by the commercial activity of the followers of Mohammed. *Mosul* in Mesopotamia, is said to have been the origin of the word muslin, while *Calicut* gave its name to calico, and *Nankin* to the cotton fabric known as nankeen. The cotton-plant grows plentifully on the borders of some African rivers, and a few years ago was introduced into Egypt, where the soil and climate appear to be admirably fitted for its growth. As the seed planted there was from the Georgian Sea-island plants, the cotton brought to England from Egypt is known as *Sea-island Egyptian cotton.*

On the discovery of America, the cotton manufacture was found to be in an advanced state in that country. Cortez sent presents to Charles V. of cotton mantles of various colours, waistcoats, handkerchiefs, counterpanes, tapestries, and carpets of cotton. The rest of Europe received from Spain the cotton manufacture. The plant was grown at Valencia, and an extensive manufacture of sail-cloth and fustian was set up at Barcelona. Cotton yarn began also to be imported into Europe from Syria and Asia Minor. The early history of our own attempts at this manufacture, refers to a heavy and coarse fabric called *muslin,* but of too rude a kind to deserve much notice. No fine goods appear to have been made in Europe until the invention of the spinning machinery of England. The time of the actual commencement of the cotton manufacture in our country is difficult to settle: the more so, that there is a confusion of terms, by which the woollen and linen fabrics of Lancashire were called *cottons.* Camden speaking of Manchester in 1590, alludes to "the glory of its woollen cloths, which they call *Manchester cottons.*" The earliest actual record of the cotton manufacture is by Roberts, in 1641, who says of the people of Manchester: "They buy *cotton-wool* in London, that comes first from Cyprus and Smyrna, and at home worke the same and perfect it into *fustians, vermillions, dimities,* and other stuffes, and then return it to London, where the same is sold, and not seldom sent into forrain parts, who have means, at far easier termes, to provide themselves of the said first materials."

The preparation of yarn for the weaver was formerly a domestic employment, common to all ranks of society in England, as the term "spinster" universally applied to unmarried females sufficiently shows. The distaff and spindle were the earliest instruments employed. The former was a stick or reed 3 feet long, with a fork near the top, on which the carded cotton was wound. This distaff was held under the left arm, and the fibres of cotton drawn from it, and twisted spirally by the action of the thumb and fore-finger of the right hand. The spindle was a reed scarcely a foot long, in fact, a mere winder on which to wind up the thread; at the top was a slit to attach the thread, and at the other end was a whorl or wheel to steady it. The thread being attached to the spindle was drawn from the distaff until a sufficient length had been gained for the attached spindle to touch the ground, a fresh turn being frequently given to the spindle to increase the twist of the thread. As soon as the spindle reached the ground, "a length" was said to be spun, and the

spinster, winding it up on the spindle, and securing it firmly in the slit, proceeded to spin another "length." The Hindoos make their spindles from the shrub *Euonymus*, which has hence obtained the popular name of the spindle-tree. These simple implements were superseded in England in or soon after the reign of Henry VIII. by the spinning wheel, which had been in use for ages in Hindustan; and in improved forms, and according to the places whence we received it, was called in this country the *Jersey wheel*, *Saxon wheel*, &c. This was a large wheel, over which passed a band or cord in connexion with the spindle, and giving motion to it. One slow revolution of the large wheel of course produced rapid and numerous revolutions of the spindle on its axis. The cotton was first *carded* or brushed with coarse wire brushes, called *hand cards*, until the fibres were all arranged in one direction, and soft fleecy rolls had been produced, each a foot long: one of these was taken and attached to the spindle, the spinster then turned the wheel with one hand, and drew out the carding with the other. The motion thus given to the carding twisted it spirally, and increased its length. It was then wound upon the spindle, and another carding was attached to it, twisted, and drawn out like the other, so as to form a continuous thread, or *roving*. This was called coarse spinning, and a repetition of the process was necessary to reduce this roving to a tolerably fine thread. But at the best it was a very unequal thread, its evenness depending on the greater or less delicacy of touch of the spinster. It was necessary to use the firmer and more equal thread of flax for the warp, the woof only being of cotton. The spinning wheel gave profitable domestic employment to women and children, but its use was, perhaps, the origin of infant labour, and caused severe tasks to be inflicted on the young. All these efforts could not meet the rising demand for cotton yarn, and a weaver had sometimes to walk three or four miles of a morning, and call on five or six spinsters before he could collect enough weft to serve him for the remainder of the day; and when hard driven for a supply, he would quicken the exertions of the spinners by the promise of a new ribbon, or a gown. This great difficulty felt by weavers of getting a due supply of yarn for their looms, at last stimulated the invention of one of their number, an industrious but illiterate man, James Hargreaves by name. He had often tried to spin with two or three spindles at once, holding the several threads between the fingers of his left hand, but the horizontal position of the spindles frustrated his attempt. It is said that one day his children upset the spinning wheel while he was at work, and as he retained the thread in his hand the wheel continued to revolve horizontally and the spindle vertically. This excited his close attention, and he continued to turn the wheel as it lay on the floor, and to watch the motion of the spindle with an interest which no one about him could understand. The happy thought had now occurred to him that if a number of spindles were placed upright, and side by side, many threads could be spun at once. He, accordingly, contrived a frame, where eight spindles were placed in a row, and eight rovings attached to them, the other ends being received by a fluted wooden clasp, which opened and shut like a parallel ruler, and when pressed together held the threads fast. This clasp was drawn by the left hand along the frame to a considerable distance from the spindles, while the spinner with his right hand turned a fly wheel, thus keeping all the spindles in rapid motion, and giving the cotton the requisite twist. Eight lengths being thus spun they were wound on the spindles, and the clasp being returned to its first position, was again opened by a simple contrivance called the "knocker off," and fresh lengths of roving attached and spun out as before. The number of spindles afterwards attached to this frame was increased from eight to eighty. Thus arose, about the year 1764, the *Spinning Jenny*, Fig. 629, named, as

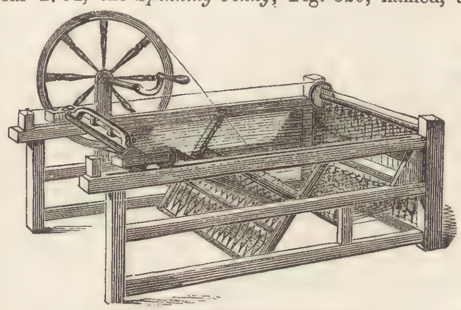


Fig. 629. THE SPINNING JENNY.

some say, from its doing the work of a female, but as a grandson of Hargreaves has informed the Editor, from the word *gin*, a contraction of *engine*, the new machine being called a *ginny*, and the process *ginning*. These terms are said to have begun with Hargreaves' wife, who commended her daughter Mary's spinning with the new frame by saying,—"Thou *gins* away famously." Coming from so good a source, we may perhaps conclude that this is the true origin of the word, though it is frequently said to have arisen from the Christian name of the inventor's daughter, and it is very possible he may have had a Jane among his twelve children. Hargreaves kept his discovery quiet for some time, but the quantity of cotton spun by his family excited suspicion, and at last other spinners broke in, and destroyed his machine. He then removed to Nottingham, and erected a small spinning mill on the jenny plan. He also took out a patent, and on its infringement he brought an action, and a deputation waited on him with an offer of 3000*l.* for permission to use his machine. In an evil hour he declined this, and subsequently, when it was found that he had sold several of his machines before he took out his patent, he lost all claim to redress and compensation, and was very little benefited by what was an invention of great national importance. He died in 1778, not in poverty and distress, as it is often stated, for he left his family 500*l.*, but still without the reward which his merits deserved. The late Sir Robert Peel bestowed on his youngest, and only surviving daughter, a few years back, the sum of 250*l.* from the Royal Bounty Fund.

The invention of Hargreaves, important as it was, did not keep pace with the great and increasing demand for yarn. But there was another genius at work, soon to produce more powerful machinery, which would, to a certain extent, throw into the shade all previous inventions. This was Richard Arkwright, of Preston, in Lancashire; a poor youth, apprenticed to a barber, afterwards a barber on his own account at Bolton, and a dyer of hair for the wig-makers, in which latter art he is said to have contrived and employed a chemical process of some value. Besides this he was a mechanical genius, and busied himself, as many self-educated mechanics are accustomed to do, in the pursuit of that will-o'-the-wisp, *perpetual motion*. In this way he became acquainted with Kay, a clockmaker at Warrington, who is said to have given him the first idea of a scheme for spinning by rollers. As early as 1738, Wyatt, of Birmingham, and his partner Paul, a foreigner, had taken out a patent for such a machine, being the invention of Wyatt; but this, after two years' trial, was given up. A similar machine is said to have been made by one Highs, a friend of Kay, the clockmaker; but this does not rest on very sure evidence. At any rate, the idea must have been imperfect, if conveyed in this way at all, for Arkwright wrought with long patience and constancy, and abandoned every other employment to perfect and complete his idea of a spinning machine. His great poverty made it difficult for him to get the requisite assistance in the heavier parts of the work; he, therefore, made application at his native place, and at length, money being kindly supplied by Mr. Smalley, the head-master of the Grammar School at Preston, Arkwright's machine was brought to completion, and first fitted up in the parlour of the house belonging to the school.

Arkwright now removed to Nottingham, where Hargreaves had previously taken refuge, and there sought a partnership which might enable him to bring forward and patent his machine. This he found in Messrs. Need and Strutt, the latter of whom was the improver and patentee of the stocking-frame. A patent was taken out in 1769, and the partners erected a mill near Nottingham, where the machinery was worked by a water-wheel, and came in consequence to be called the *water-frame*, and the yarn, the *water-twist*. The first great improvement accomplished by the new machine, was the production of a firm hard thread fit for warps, so that linen warps were henceforth abandoned. Calico, in imitation of the Indian fabric, was also made, but this was soon checked by the Excise, who actually refused to let it pass at the usual duty of three-pence per yard, and insisted upon sixpence, as for Indian goods. The partners were put to much expense before they gained permission by act of Parliament to manufacture calico, which was to be distinguished from the foreign by three blue stripes woven in the warp of both selvages, and by the word "British Manufactory" stamped upon it. Arkwright's active mind was continually engaged in improving his own machines, and also those used in the preparatory processes of the cotton manufacture. He was the first person who ever erected a cotton-mill, and formed a distinct idea of all the processes to be carried on therein. He knew all the changes the fibres must undergo, from the tangled cotton-wool to the finished thread, and when an imperfection occurred in his yarn, he could in a moment state which of the processes had in that case been defective. Thus the merit of perfecting the carding machine belongs to Arkwright, for he combined the various improvements on the old hand-cards, which had been made by other men, with clever devices of his own. In 1775, he had made such extensive alterations in a series of machines, including carding, drawing, and roving machines, that he considered himself justified in claiming them as his own by a second patent. His fame was now great, and in 1782 it was calculated that 5,000 persons were employed in his factories, while numbers of manufacturers flocked to buy his patent machines. The origin of the factory system is referred to this period, although a few silk-mills had existed since 1719. The cottages of the spinners could not accommodate the new forms of machinery, which also required substantial buildings to bear their weight, and water-wheels to work them to advantage.

Arkwright was not allowed to enjoy his second patent very long; it was disputed by the Lancashire spinners, and eventually thrown open to the public. Arkwright opposed the verdict, and there were several trials, but he lost his cause, and this was undoubtedly a national advantage, for the manufacture soon acquired an extent and importance which could not have occurred had it continued to be a monopoly. Arkwright shared with others in the great prosperity which followed. He was looked to in adjusting prices, he was advanced in importance by being appointed High Sheriff of Derbyshire, and was at length knighted, on the occasion of his presenting an address to king George III. So much for the barber's apprentice, who made his own fortune by wonderful ardour, energy, and perseverance. He was accustomed to labour from five in the morning till nine at night, and to make up for the defects of his education, he began at more than fifty years of age to steal two hours from sleep each day that he might learn English grammar, writing, and orthography.

Hargreaves and Arkwright had thus produced spinning-machines of great value, and by their means had opened a new era in the cotton manufacture. But the yarn they obtained was not of fine quality, and was therefore only adapted for the stronger and coarser descriptions of goods. The happy thought now occurred to a young weaver, Samuel Crompton by name, to combine the roller spinning of Arkwright with the jenny spinning of Hargreaves, and in doing so, to get rid of some objections which applied to them separately. By a perfectly original contrivance he effected this union, and the new machine was called the *mule*, or the *mule-jenny*. In this machine, the spindles instead of being stationary as in the former cases, were placed on a movable

carriage, or "mule," which was wheeled out to the distance of about five feet, in order to stretch and twist the thread, and wheeled in again to wind it on the spindles. This invention was perfected in 1779. Crompton's object had merely been to supply his own loom with good yarn; but when he found he could not do this in peace, owing to the curiosity of many persons, who even climbed up to his windows to watch him at work, he laid his invention before a number of gentlemen and others, who paid a guinea each to examine it. He thus raised about fifty pounds, with which he constructed another machine, larger and more perfect than the first. The mule jenny not being protected by patent, soon came into most extensive use, without any great benefit to the inventor. Yarn fine enough for muslins was spun by it, hence it was called the *muslin-wheel.* It was also known as the "Hall-in-the-wood wheel," from an old mansion in a retired and beautiful spot

Fig. 630. HALL-IN-THE-WOOD, NEAR BOLTON.

near Bolton, where Crompton lived. This mansion has been described as "one of the most perfect specimens of the domestic architecture of our Saxon ancestors, and of their descendants the Franklins, or old country gentlemen of England, who never bowed their head to the Norman yoke, and who refused to adopt the fashions imported from the continent." Beyond is the hill, on which stands the busy town of Bolton, while the intervening valley is studded with factories and bleach works. In the year 1812, some gentlemen of Manchester memorialized the government on the subject of Crompton's claims, and the result was a grant of 5,000*l.* With this sum Crompton established his sons in the bleaching business, but from some unfortunate circumstances they failed, and the father was again reduced to poverty. His friend and biographer, Mr. Kennedy, then exerted himself to raise a subscription, and with this a small annuity was purchased, but Crompton did not live to enjoy it more than two years. He died in 1827. His machine as first invented was adapted to carry 20 or 30 spindles only; now double mules are made carrying 1,100 or 2,200 the pair, one spinner being competent to manage them. Self-acting mules are also now constructed, the only manual labour being to join the broken threads and keep the machine in order.

At one time, Crompton's machine seemed likely to supersede all others, but when the *power-loom* came into use, twist for warps was required to possess that strength and wiry smoothness which the water-frame produced; that machine was therefore remodelled, and came into use under the name of the *throstle,* on account of the singing sound produced by the motion of the arms of the spindle.

The causes which have determined the principal locality of the cotton trade in Manchester and its neighbourhood, are certain natural and physical advantages which belong especially to the southern part of Lancashire, namely, the possession of water-power, fuel, and iron. These advantages also belong, in a less degree, to the south-western part of Yorkshire, to Cheshire, Derbyshire, and Nottinghamshire, and also to Renfrewshire and Lanarkshire in Scotland, and consequently these districts share in the cotton trade.

Where water-power, fuel, and iron are abundant, machinery may be manufactured and set in motion at the smallest cost; and the processes of making and finishing cloth, depending, as they chiefly do, on the agency of water and heat, may also be conducted with advantage.

"The tract lying between the Ribble and the Mersey, is surrounded on the east and north by high ranges of hills, and has also hills of some magnitude in the hundred of Blackburn and Salford; owing to which cause the district is intersected by a great number of streams, which descend rapidly from their sources towards the level tract in the west. In the early part of their course, these streams and streamlets furnish water-power adequate to turn many hundred mills; they afford the element of water, indispensable for scouring, bleaching, printing, dyeing, and other processes of manufacture; and when collected in their larger channels, or employed to feed canals, they supply a superior inland navigation, so important for the transit of raw materials and merchandise."[1] No less important is the great abundance of coal found in the very same district. Beds of this invaluable mineral lie beneath almost the whole surface of Blackburn and Salford hundreds, and run into West Derby, to within a few miles of Liverpool, and being near the surface, they yield their treasures easily. The southern part of Lancashire contains very little iron, but being at no great distance from the iron districts of Staffordshire, Warwickshire, Yorkshire, Furness, and Wales, with all of which it has easy communication, it is as abundantly and almost as cheaply supplied as if the iron was got within its own boundaries. Another great advantage of Lancashire is its well situated port, Liverpool, "through the medium of which it receives from Ireland a large proportion of the food

(1) History of the Cotton Manufacture in Great Britain, by Edward Baines, Esq. Jun. London, 1835.

that supports its population, and whose commerce brings from distant shores the raw materials of its manufactures, and again distributes them, converted into useful and elegant clothing, amongst all the nations of the earth." Through the same means, a plentiful supply of timber is obtained for building. To these natural advantages must be added the acquired advantages of canal and railroad communication with other parts of Britain.

The American cotton grower frequently consigns his cotton to this country for sale on his own account; but about three-fourths of the whole quantity sent is consigned by mercantile houses. The cotton is sold in Liverpool by brokers employed by the importers, and they charge 10*s.* per cent, for their trouble in valuing and selling it. The purchasers are the Manchester cotton-dealers and spinners all over the country, and they also employ brokers at the same rate of commission to make their purchases. The cotton is principally bought and sold by sample, and the purchasers very rarely examine the bulk. Fig. 631 is a bag or bale of cotton.

Fig. 631.

Sorting.—When the cotton arrives at the mill, the bags are unpacked and sorted. The *sorting* requires judgment, because the qualities of the cotton differ somewhat in different bags, and the yarn to be spun from it must be of uniform quality. In order to equalize the different qualities, the contents of all the bags of one lot are mixed together in the following ingenious manner. A space is cleared and marked out on the floor, and the cotton of one bag is scattered all over this space, or on a clean mat spread thereon, so as to cover it exactly; the contents of the second bag are in like manner spread over the first; the third upon the second, and so on, until all the bags are thus formed into a kind of cotton stack, called a *bing* or *bunker*. While this is in process of formation, it is trodden down by men and boys, just as hay is in stacking. Now it will be obvious that if a supply of cotton for the purposes of the mill be taken from the side of this bing, tearing it down with a rake from the top to the bottom, a portion of every bag must be taken in every quantity thus pulled down, and in this way uniformity in quality and colour may be ensured. It is usual in forming a bing with different qualities of cotton to use those which have a similar length of staple; and for making the lower descriptions of yarn, some of the waste cotton of the mill is also used. For yarns of higher numbers, and for warps, a finer quality of cotton is selected. Fig. 632 shows another method of forming a bing. "Much skill may be shown in the suitable intermixture of different kinds of cotton, in order to improve a weak-stapled quality, and make it work into good yarn. Soft, short, riband-like filaments are best adapted for spinning into wefts; firm, long, and cylindrical ones

Fig. 632. SORTING AND PULLING.

are best adapted for making the wiry warps and lace-thread yarns. Cottons which differ much in the length of their staple and form of their fibres do not draw, rove, or spin well together. Coarse wefts are made from Surats, Bengals, and the inferior Uplands, with waste tops from the blowing-machine; but the better wefts for muslins require the finer staples of Bahia, Demerara, New Orleans, and the inferior sea-islands. Warps are spun from New Orleans, Egyptian, Maranham, Pernambuco, and sea-island, &c." [1]

Willowing.—The cotton in the bing is matted together by the pressure to which it was subjected in packing, and it is also contaminated with mud, dirt, and other impurities. The fibres are opened, and the cotton is cleaned by a machine called a *willow*. This consists of a box or case, containing a conical wooden beam, studded over with iron spikes, and passing between other spikes fixed in the case or cover of the machine. The beam is made to revolve rapidly, and the cotton as it is torn down from the bing, being put in at one end of the machine, is caught by the spikes, and tossed and shaken about, and gradually driven forward to the other end. The sand and other heavy impurities fall out through an open grating at the bottom of the machine; the dust and lighter matters pass off through a series of wire openings into a shoot in which a draught is created by means of a revolving fan, while the cleaned cotton passes down a shoot into the floor below. In some of the early forms of this machine, a cylindrical cage was made of *willows:* hence the origin of the name.

Batting.—Cottons of fine quality are not passed through the willow: they are beaten or *batted* with twigs of hazel or holly, 3 or 4 feet long, upon a frame,

(1) "The Cotton Manufacture of Great Britain." By Andrew Ure, M.D. &c. 2 vols. 12mo. London, 1836. This useful and elaborate work, although published so long ago, is still the fullest and most complete treatise that we possess on this important subject. It has been our chief authority in this Article, and ought to be studied by every one who wishes to become acquainted with the cotton manufacture in all its minute details. Various improvements have been introduced into the manufacture since the date of its publication, but all the main features remain unchanged.

the upper surface of which is made of cords, so as to form a kind of elastic grating. A woman with a rod in each hand, (Fig. 633,) beats the cotton violently, by which means the tangled locks become completely

Fig. 633. BATTING COTTON.

opened, and are made quite clean, without injuring the staple: the loose impurities fall out through the openings between the cords; but the fragments of seed-pods, which adhere somewhat firmly to the cotton, are picked out by hand.

SCUTCHING, BLOWING, and LAPPING.—For the coarser varieties of cotton, the batting is performed in what is called a *scutching* or *blowing-machine.* A few years ago, when the Editor visited Mr. Orrell's mill at Stockport, the following was the arrangement: "The cotton, as it was shot down from the willow, was received upon an endless band called a *creeper*, ingeniously covered with laths of wood moving upon rollers: it supplied cotton to the various blowing-machines, placed at equal distances apart across a long room. Each machine was attended by two lads, one of whom weighed a portion of the cotton, while the other spread it upon an endless band employed to feed the machine. This band was also formed of laths, placed crosswise, and fastened together, in preference to cloth, which is apt to sink along the middle, and thus feed the machine irregularly. Two or three of the laths were painted black, for the purpose of dividing the surface of the feeder into two or three equal parts. The feeder being constantly urged, with a slow motion, towards the mouth of the machine, it was the duty of the attendant, as soon as a black lath appeared, to begin to spread the weighed quantity of cotton, and to make it cover the whole surface until another black lath appeared: he was then ready to spread another weight of cotton. Thus, while one part of the feeder is constantly supplying the insatiable appetite of the machine, another part returns for a fresh supply. As soon as the cotton enters the jaws of the machine, it is seized by two rollers, and immediately exposed to the blows of a *batting-arm*, or beater, which is turned round with great velocity within a kind of drum, of which the arms of the beater form the diameter. The solid impurities fall through a grating, but the dust and lighter matters are sucked up through a shoot, in which the air is rarefied by a revolving fan. The wind produced by the batting-arm drives the light cotton filaments onward, where they are assaulted by another batting-arm: they are again urged forward, and blown with tolerable regularity over the surface of a wire-gauze drum, which is constantly revolving. Beneath this drum, and in close contact with it, is an endless band, moving on rollers, which receives the cotton, and conveys it out of the machine. The pressure of the drum upon the band condenses the cotton into a filmy sheet; that is, the fibres cling together sufficiently to allow the cotton to be wound upon an iron rod as it leaves the machine, and in this state it is called a *lap.* The advantage of this is, that a uniform thickness can be presented to the carding-engine, which is a necessary condition."[1]

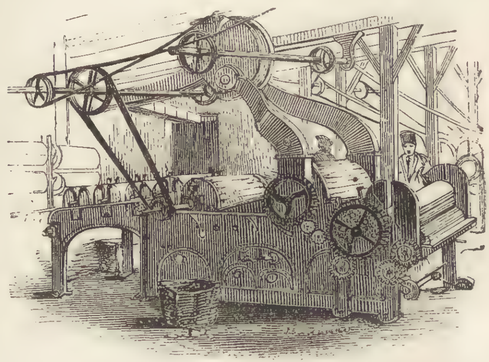


Fig. 634. BATTING AND LAPPING MACHINE.

The means by which these arrangements are carried out will be understood by referring to the longitudinal section of a batting and lapping machine, Fig. 635. The feed-apron is about 8 feet long: part of it is shown at A, where one end passes over a roller *a*, and its further end over a similar roller beyond the limits of the figure. The willowed cotton is spread by hand in weighed quantities, about 2 inches thick, upon the apron-cloth A, and is carried forward by it, at the rate of about 3 feet per minute, to the feed-rollers, *b*, which are pressed together by a weight acting on a lever *c* upon the brasses of the top rollers. A wooden roller *d* keeps the cotton close to the apron, and guides it between the feed-rollers, which are small coarsely-fluted iron cylinders. B is the first beater, consisting of two flat bars *e e*, fixed at right angles upon a revolving shaft, so as to strike upon the cotton filaments as they issue from between the feed-rollers. This, the scutching-shaft, makes 2,000 turns per minute. C is the *harp*, a grating or grid, in the form of a quadrant of a cylinder, composed of long flat bars, against the edges of which the cotton is scutched by the beaters, and thereby thoroughly opened, after which it is wafted upon the endless apron D. This apron is formed of thin spars of wood, about $\frac{3}{4}$ inch broad, and $\frac{1}{2}$ inch apart, fixed

(1) "The Useful Arts and Manufactures of Great Britain." By Charles Tomlinson. Published under the direction of the Committee of General Literature and Education, appointed by the Society for Promoting Christian Knowledge. 2 vols.

at their ends to two endless leather straps, which turn round the rollers *f* and *g*, which are driven by the outside wheelwork, seen in Fig. 634. Near the end of the apron is a revolving cage cylinder E, enclosed under the cover *h h*, in the top of which is a pipe *i* in communication with a revolving fan. This cylinder allows the dust to pass through it, and also serves to spread upon the apron the loose cotton filaments into a level fleece, which passes off under the wooden roller *h*, and is thence drawn in by the second pair of feed-rollers, *l*, in order to be exposed to a second scutching by the beater-bars at F, the axis of which

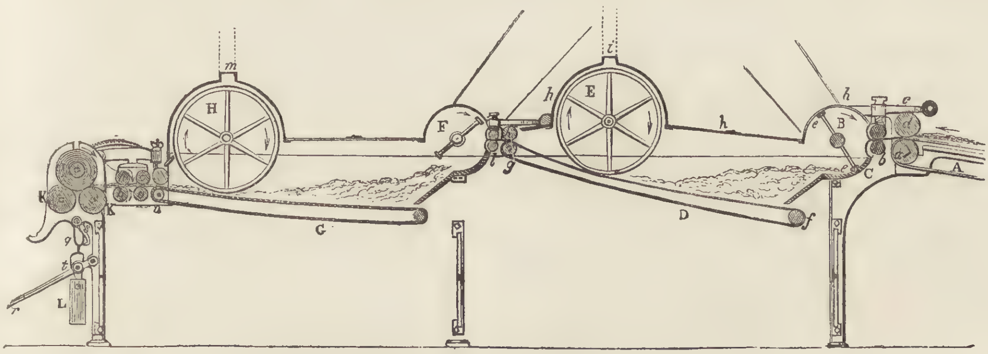


Fig. 635 SECTION OF BATTING AND LAPPING MACHINE.

revolves 2,200 times per minute. This beater delivers the filaments upon a second apron G, where it is exposed to the sucking action of a second sieve cylinder, communicating by the orifice *m* with the fan ventilator. There the cotton is again formed into a fleecy mass, and is carried through between the two pairs of iron rollers *o o* and *p p*, the upper ones being weighted. These rollers deliver the compressed fleece to the wooden lap cylinder I, whose axis is loaded by hanging weights as at L, so as to bear down between the two rollers K K, which, revolving both in one direction, carry round with them, by friction alone, the lap cylinder. As this cylinder increases in diameter, the links *q* progressively rise up, with their weights L, so that the pressure continues always uniform. When the coil of lap has attained the proper size, the twin rollers *o o*, with the aprons, cages, and feed-rollers, throw themselves out of gear, whilst the twin rollers *p p* and the lap cylinders continue to revolve, whereby the fleece is torn or cut across in the middle line between the two pairs of twin rollers. The attendant now lifts the lever *r*, which raises the links *q*, and suspends the weights L by the hook *s*. In this way he relieves the axis of the lap cylinder, removes it, and puts an empty one in its place. He next throws the machinery once more into gear, disengages the connecting-rod *t* from the hook *s*, and restores the action of the weight, while he guides the beginning of the fleece round the empty roller.

In fine yarns, the laps are prepared by hand. In Mr. Houldsworth's mill, at Manchester, the Editor watched the process, and it was performed in the following manner :—A lad was furnished with two qualities of cotton in separate baskets, from one of which he took a certain quantity, and put it, together with a small weight, into a scale-pan; when the scale-pan, thus loaded, counterbalanced the weight at the opposite end of the beam, the small weight was taken out of the scale-pan, and its equivalent was made up from the second basket. In this way, cotton of various degrees of fineness could be mixed in any proportion. If, for example, a yarn is to be produced from two qualities of cotton, in the proportion of 3 of one to 2 of the other, the large or counterpoise scale-weight is $1\frac{1}{4}$ or $\frac{5}{4}$. The lap-maker first puts into the scale-pan a weight equal to $\frac{2}{4}$ths, and cotton equal to $\frac{3}{4}$ths; then taking out the $\frac{2}{4}$ths weight, its place is supplied by another sample of cotton. But to return to our description:—The cotton thus weighed out was taken to a canvass strip, one-half of which was extended along a kind of frame, the other half resting on the floor. The lad distributed the cotton over this cloth, batting and flattening it out with a kind of fan, formed by tying four or five thin rods together. The canvass thus covered with cotton was then rolled upon an iron spindle, and the act of rolling drew upon the frame the second half of the canvass from the floor: this was also covered with cotton and then rolled up. In spinning fine yarns, all the preparatory stages require great care, and the formation of these laps for the carding-engine is a work of nicety. Should the cotton be spread irregularly, the uniform thickness of the yarn may be interrupted. Some manufacturers even make a compensation for hygrometric changes in the weight of the lap: the cotton varies slightly in weight according as the weather is wet or dry; and as a metal counterpoise is uniform, a variable counterpoise is made by packing a hollow perforated copper tube or ball with cotton: as this

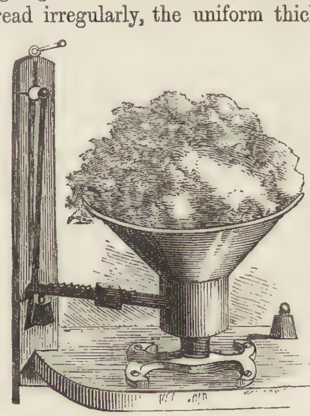


Fig. 636.

weight is about as much affected by atmospheric changes as the cotton which is to be weighed, an equality is thus preserved in forming the laps.

Of late years a very convenient balance, Fig. 636, of American invention, has been used. It acts on the principle of the steel-yard. It is also shown in Fig. 637.

Fig. 637. LAP MACHINE.

Carding.—The cotton, as left by the preceding operations, is in a tangled state, and not entirely free from impurity; but by the next operation—that of *carding*—the fibres are separated, made somewhat parallel, and freed from the remaining impurities. A cotton card is a sort of wire brush, made of bands or fillets of leather, or of alternate layers of cotton, linen, and India-rubber, pierced with numerous holes, in which are fixed bent pieces of hard-drawn iron wire, called *dents* or *teeth*. Each piece of wire is first bent at right angles, as at *a* and *b*, Fig. 638; then each limb must receive a second bend, as at *c* and *d*, Fig. 640, at a determinate obtuse angle, which must be invariable for the same set of cards. The teeth thus formed of equal size and shape must stand at equal distances, and be equally inclined to the curved surface of the drum round which the cards are to be lapped. The leather must also be of equal thickness throughout.

These conditions, which are necessary to good carding, cannot be secured in hand-made cards. Accordingly, many attempts have been made to construct a card-making machine, the most successful of which is that by Mr. Dyer. The leather is first prepared for it by a planing machine, which cuts it into fillets of the proper length and breadth; each fillet is then wetted and stretched so as to produce an even surface; it is then passed between rollers against a nicely-adjusted knife edge, which shaves it down to a uniform thickness. The fillet is then wound upon a roller, and passed between two guide rollers to a receiving roller above the card-making machine, where the fillet is held fast and is stretched by a clamp. The wire for the teeth is contained on a drum at the side. The action of the card-making machine is as follows:—Two prickers advance, and make two holes in the leather; a pair of sliding pincers next seize the wire, and wind off from the drum a length exactly sufficient for the teeth; a tongue of steel holds this piece of wire exactly in the middle, while a knife advances and cuts it off from that part of the wire held in the pincers. Steel fingers next advance, bend the piece of wire just cut off, and carry it forward to the holes previously made by the prickers. The points of the wire are seized on the opposite side of the leather, and a bar rises up and bends the two limbs, so as to form a knee in each. A pusher then acts from the opposite side, and drives home the wire into the leather, which is then shifted by the guide rollers, and another wire is inserted as before. This machine works so rapidly as to put in 200 teeth every minute, and to complete a length of 20 feet of card in a day. At Messrs. Curtis's factory, at Manchester, the writer saw 90 card-making machines at work in one room. Some of these machines insert the dents in lines across the fillet, at right angles to its length; others insert them in oblique lines. After the cards are completed by these machines they are finished and made true by grinding, and when in use they are ground down from time to time until the teeth are worn out.

Fig. 639 will explain the action of the cards in disentangling the fibres of the cotton wool, and laying

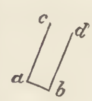


Fig. 638.

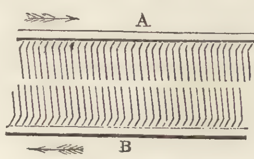


Fig. 639.

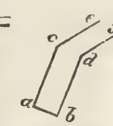


Fig. 640.

them parallel. If the two cards A and B be moved in opposite directions with a tangled tuft of cotton between them, the fibres will be seized by all the teeth, one card pulling them one way, and the other card the opposite way, until, by repeated applications of the cards, the fibres are disentangled and laid in parallel lines, each card taking up and retaining a portion of the cotton. All the cotton may be got upon one card by reversing the position of the two, and placing them as in Fig. 641, in which, by drawing the upper card *a* over the lower *b*, the teeth of the latter can offer no resistance, and it will give up its cotton to the upper card.

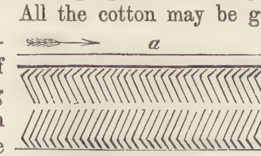


Fig. 641.

To apply these principles to the carding engine given in section, Fig. 643. The main carding cylinder, A, is formed of parallel segments of mahogany, screwed upon rings of cast-iron fixed to the central shaft. Each of these segments has nailed to it a length of card leather, or card-cloth, equal to the width of the main cylinder. A portion of the upper part of this cylinder is covered with parallel segments of mahogany, B, called *card-tops*, the ends of which rest upon the heads of adjusting screws projecting from the side framing, and they are kept in their places on the frame by pins passing through their ends. Their concave surfaces are covered with a narrow fillet of card-leather. The small rollers D, E, F, G, called *urchins*

or *squirrels*, are covered with card fillets wound spirally round each from one end to the other. The engine is fed by means of a pair of fluted iron rollers, *h*, pressed together by a screw, *c; h* is a feed-board,

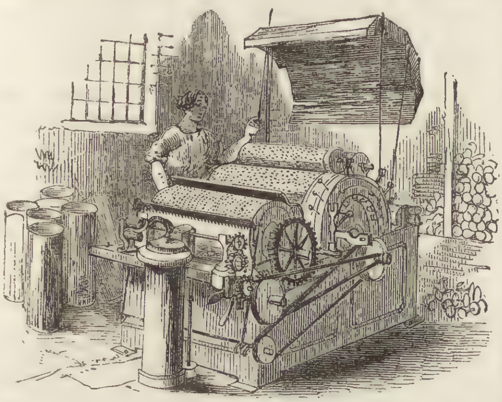


Fig. 642. CARDING ENGINE.

along the surface of which the fleece, unwound from the lap-roll, I, by the acting roller, K, advances to the feed rollers. The first roller-card, D, called the

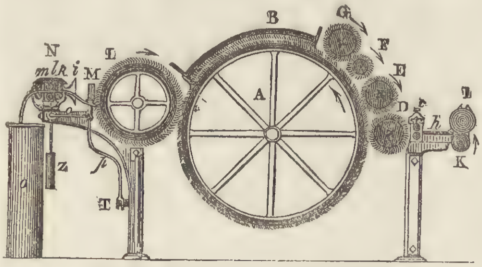


Fig. 643. SECTION OF CARDING ENGINE.

licker-in, turns with much less velocity than the drum-card, and draws in single filaments from the feed-roller. These filaments are immediately stripped from it by the large cylinder, A, to be again teazed out by the teeth of the second roller, E, which moves still more slowly than D, thus serving to pick off the knots from the drum. These knots being carried round by the roller, are again presented to the cylinder, D, as it revolves nearly in contact with E. The roller D next transfers the teazed-out filaments to the drum, blending them with fresh ones supplied by the feed-rollers. The tufts, or knots, which escape the action of the first two rollers, D and E, are almost sure to be laid hold of by the fourth roller, G, which is placed closer to the drum, and moves with the same speed as E. The knots caught by G are teazed out by F, which is nearly in contact with it, but revolves at a quicker rate, but not so fast as the surface of the drum. The loosened fibres are thus seized by F, and once more transferred to the drum, whence they proceed, and receive a second teazing from the roller G. Any knots which still remain are arrested by the first flat top cards, and held there till they are disentangled by the rotation of the drum. These flats are occasionally taken out and cleaned, and the first flats require more frequent cleaning than the others. After the filaments of cotton have passed by the flats, they lie in nearly parallel lines among the card teeth of the drum, and from this they are removed by a smaller drum card, which is covered spirally with fillet cards, and is called the *doffer*. This doffer, L, turns slowly in contact with the drum, and in an opposite direction, and thus becomes covered with a fine fleece of cotton,[1] which is removed from the opposite side of the cylinder by the vibrating action of the doffing knife M, Fig. 644. This consists of a blade of steel

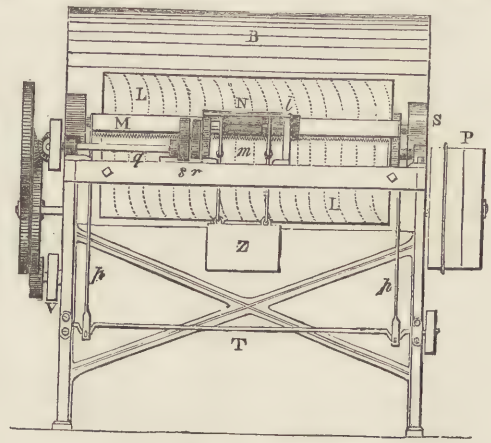


Fig. 644. THE CRANK AND COMB.

toothed at its edge like a fine comb, and it is made to strike down, by means of the crank T and the upright rods *pp*, with a rapid motion tangentially over the points of the cards. In this way a fine transparent fleece is removed, equal in breadth to the length of the card on the doffer, but its breadth is immediately contracted into that of a narrow riband, by being passed through the funnel, *i*. Fig. 643. This riband is called a *card-end* or *sliver*, and it is consolidated by being passed between three pairs of iron rollers, *k,l,m;* the bottom rollers of *k* and *l* are finely fluted, or channelled, and the top ones are covered with two coats, the inner of flannel and the outer of leather. The upper rollers are pressed upon the lower ones by weights, Z, hung upon their axes. We here first observe the effect of the beautiful invention of passing the cotton between pairs of rollers moving with different degrees of speed. The pair of rollers, *l*, moves faster than the pair *k*, the effect of which is to draw out and straighten the filaments. The card end, after being spread by the first two pairs of rollers into a flat riband, is passed through a vertical slit in a plate N, situated between the second and third pairs of rollers, which gathers it up into an elliptical sliver; it is next drawn through two smooth rollers, *m*, which are slightly pressed together, and lastly it is received into the tin can, *o*, in the shape of a spongy, slightly coherent sliver. In fine spinning the cotton passes through two carding engines; the first, which is coarse, is called a *breaker-card*, and the second, in which the teeth are set finer, a *finishing-card*. A number of cardings from the breaker card are united

(1) The drum revolves with a surface velocity of from 20 to 30 times quicker than the doffer, according to the nature of the cotton.

together at the edges, by passing them between the steel rollers of a lap-machine; the new lap thus formed is wound upon a cylinder, from which the finishing card is fed.[1]

The inventor of the carding-engine is not known with certainty. It appears, however, that in 1748, Lewis Paul patented two different machines for carding, in one of which the cards were arranged on a flat surface, and in the other on a drum. The cards were arranged parallel to each other and to the axis of the drum, a space being left between every two cards. The wool was put on by hand, and the cardings were taken off separately by a movable comb, the spaces between the cards regulating the substance of each carding. By this method the machines had to be stopped every time the cardings were taken off, and then had to be joined end to end to form the perpetual carding. The machine was not generally known and adopted in Lancashire for more than twenty years after the date of the patent. One of the first improvements was to fix to the machine a revolving cloth or feeder, on which a given weight of cotton wool was spread, by which it was conveyed to the machine. Arkwright further improved this by rolling up the feeder with the cotton spread upon it, as already explained, and allowing this gradually to unroll to feed the cylinder. Another improvement brought off the carded wool in a continuous fleece, forming a uniform and perpetual sliver. The doffer, which strips the wool from the large cylinder, turned off a carding of no greater length than that of the cylinder; but it was found, that by entirely covering the doffer with narrow cards, wound round in a spiral form, without having any spaces, the wool might be brought off in one unbroken fleece. But the method of stripping off the wool from the doffer was attended with many difficulties, which were at length overcome by the invention of the crank and comb, the merit of which has been ascribed by some to Arkwright, by others to Hargreaves, the inventor of the jenny. Those who defend the claim of the former say that it was communicated to Hargreaves by one of Arkwright's workmen, who chalked out a sketch of it upon the table of a public-house. The carding-engine has scarcely been improved since Arkwright's time, and the work performed by it is very satisfactory. At one end of the engine we see the cotton in its tangled knotted state, the fibres lying in every direction; at the other end we see stripped from the doffer by the crank and comb the beautiful filmy web, in which all the filaments are arranged nearly parallel, or are tending to arrange themselves in parallel lines in the sliver.

(1) Card sheets are distinguished by the number of wires in each breadth of $3\frac{1}{2}$ inches for the drum, and 2 inches for the top cards: the number of wires per inch counted in the length of the sheet leather are called *crowns*. For the preparation of yarns below 36 hanks in the pound, the cards have 80 wires per sheet for the drum: the first, second, and third tops 20; the middle tops 23; and the last 28. For the preparation of yarns of 100 and above, the cards have from 90 to 100 wires per sheet for the drum, and so on in proportion.

Drawing and Doubling.—The object of these operations is by means of revolving rollers to draw out and elongate the spongy slivers or ribands, produced by the carding engine, to straighten the filaments, and to lay them as parallel as possible. The drawing frame also serves to equalize the different qualities of the cotton, by uniting many slivers into one, whereby their mutual defects are corrected, and the sliver is attenuated preparatory to the next process. In the carding engine, many of the filaments are doubled, but they are all unfolded in the drawing. The drawing frame consists usually of three pairs of rollers, the upper one of each pair being covered

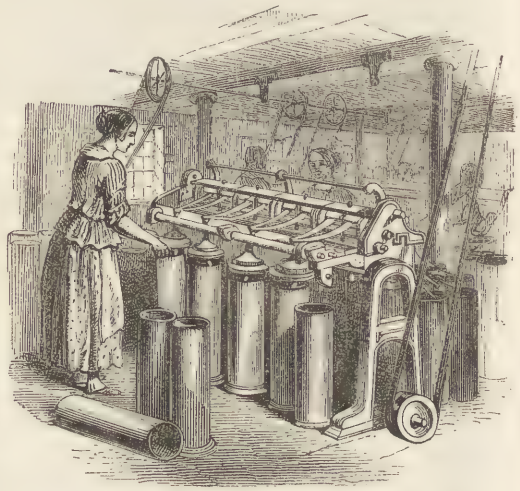


Fig. 645. DRAWING-FRAME.

with smooth elastic leather, the under ones fluted longitudinally; and by the pressure of the two, the slenderest filaments are seized and pulled out. The under rollers are driven by wheel-work with varying degrees of velocity, and they carry round by the friction of the flutings the upper ones, which are pressed upon them by a considerable weight. In Fig. 646, *a b c* are the under rollers; *a' b' c'* the upper ones; the former turn in brass bushes fixed upon iron bearings. The front roller beam is fixed, but the bearings of the two other rollers admit of being shifted in grooves, so as to make these rollers approach to or recede from each other and from the front roller until their respective distances

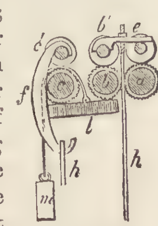


Fig. 646.

are adapted to the length or staple of the cotton wool which is being operated on; the bearings are then made fast by screw-nuts, acting on the edges of the slits in the slide bearers. The length of the top rollers is equal to that of two fluted portions of the under rollers, and in the middle of each top roller *a' b' c'*, is a smooth neck, on which the brass bushes *e f* rest, suspending weights by means of the wires, *h h'*. The two back rollers, which turn most slowly, are usually pressed down by one common weight, and the front roller by a separate weight. The three top rollers are covered

with a mahogany bar faced below with flannel, for the purpose of wiping off any stray filaments which may adhere to the top rollers. A similar bar, *l*, faced with flannel above, is made to bear, by a light weight *m*, upwards against the two front rollers, *b* and *c*, to wipe off stray filaments. The cord or wire from *m* is seen going over the neck of the roller *c*, and down again for the purpose of suspending the mahogany wiper bar *l*. G, Fig. 648, shown separately in Fig. 647, is a smooth curved plate of brass or tin plate, with a channelled surface, along which the slivers *n n*, from the respective cans at the back of the machine, are guided to the rollers. From 3 to 6 slivers are thus brought together, and united upon one fluted portion of the under rollers, or the channels may be made to converge as in Fig. 647, by which several slivers are guided in upon one fluting. The sliver, thus doubled six-fold, is drawn out in passing through the rollers into a uniform sliver of greatly increased length. Two such slivers are usually again brought together in a funnel I, and delivered by the two smooth rollers K K, into a can in front of the machine. (Fig. 645.) In some cases, one of the slivers, just after its delivery, is turned back over the smooth roller K′, and united with the slivers entering the funnel of the adjoining drawing. The object of this funnel and pair of smooth rollers, is to collect into a compact riband the cotton filaments which were previously spread out broad and thin by the drawing rollers *a*, *b*, *c*.

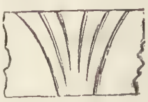


Fig. 647.

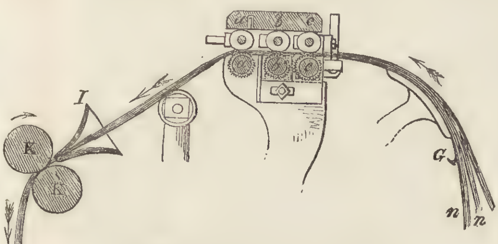


Fig. 648. DRAWING AND DOUBLING.

The action of the drawing-frame is thus further explained by Dr. Ure :—"Were the surface velocities of the three rollers *a*, *b*, *c*, Fig. 648, equal, the card ends, *n n*, after gliding over G, would pass through to the funnel I unchanged. But the velocity of *b* and *c* being greater than that of *a*, the former will deliver a greater length of riband than they receive from the first, or than this receives from the cans. Under these circumstances, the only result must be a proportional extension of the riband or sliver in the intermediate space between *a*, *b*, and *c*, and an approximation of the filament to rectilinear parallel directions during the stretching process. The rollers are so adjusted, that the drawing takes place chiefly between the first and the third pair; in fact, the middle pair can have no influence in the drawing power beyond the difference of the first and third. The intervals between *a*, *b*, and *c*, or between their lines of contact with the upper rollers, should be in all cases calculated, so that they may exceed the average length of the cotton filaments, and so that these filaments may not be placed in danger of being torn by the third pair pulling, while the second pair has a firm hold of their other ends. Between these two pairs of rollers, however, where the principal drawing occurs, the distance should be no greater than is absolutely necessary to render the drawing out of the fibres along side of each other practicable without their disruption; this adjustment being requisite to the uniformity of the drawing operation. Were that interval too great, it is obvious that a sliver, in running through the rollers, would become attenuated in the middle point between them, or might possibly break asunder; hence the drawing will be the more regular, the more nicely the interstitial space between the rollers is adapted to the length of the staple of the cotton. When one end of a filament, after being ushered in by the back rollers, is laid hold of by the second or middle pair, it is twitched suddenly forwards in a very gentle manner, so as to stretch it very slightly; but when advancing, it is seized by the front pair, and is more forcibly pulled at one end, while it is held at the other by the friction of its fellow filaments, detained by the slower rollers; the distances of the different rollers being previously adjusted exactly to the average length of the staple. The sliver thus drawn with multiplied doublings, acquires a regularity of texture which, if not impaired in the subsequent processes, ensures a level yarn to the cotton-spinner. Were the drawing of a single sliver attempted to be continued until the suitable parallelism of its filaments were effected, it would ere long become an impossible operation on account of the excessive attenuation of the riband. This inconvenience is obviated by the very simple method of associating, at each repeated drawing, several of the formerly-drawn slivers together into one riband; this is the process called *doubling*. It is an accurate imitation of what happens when we take a little cotton wool between the fingers and thumb of one hand, and draw it out with those of the other, at each turn laying the two parcels parallel again. The doubling secures the great advantage of causing the unequal parts of slivers to correct one another, and to produce finally a very uniform riband."

The following details will give some idea of the elaboration of the card ends from the commencement. Suppose 10 card ends to meet and unite in passing through the first pair of rollers, whereby they are all reduced to one sliver; the second pair reduces every inch of this compound sliver into about 2 inches, and the third pair of rollers extends these 2 inches into 10; so that the result of this first operation, is a sliver of the same thickness as one of the 10 card ends, but of 10 times the length. Next let us suppose that 10 cans filled with the compound sliver are passed on to a second drawing-head, and the 10 *drawings* are again doubled and drawn out into one; that 12 of these are doubled and drawn out at a third head; that 12 of these are doubled again and drawn out at a fourth head; and lastly, that 6 of these are doubled and drawn out at a fifth head.

Now, collecting all these numbers together, it will be seen that before a thread is attempted to be spun, the fibres are placed parallel to each other 86,400 times; for $10 \times 10 \times 12 \times 12 \times 6 = 86{,}400$. The drawing is carried on to this extent only in fine spinning. For coarse numbers, 6 card-ends are usually passed through the first drawing-head, and formed into one riband; 6 of these ribands are again formed into 1; 6 of these make a third sliver, and 5 of these are passed through the last drawing-head. Thus the doubling of the fibres of the cardings has been multiplied $6 \times 6 \times 6 \times 5 = 1080$ times.

We have been thus minute in noticing drawing and doubling, as the quality of the yarn depends greatly on the success of the process. It is stated of Arkwright, the perfector if not the inventor of the process, that when any defects appeared in his yarns, he told his people to look to their drawings, for if they were right, everything else would be so too.

The drawing-frames require constant watching to supply the place of the cans that are emptied with full ones, and also to mend the feeding sliver ends whenever one of them breaks. This duty is performed by a young woman named the *drawing tenter*. The machine is stopped instantly by moving a lever, which throws the strap from the working or fast pulley upon the loose pulley. The receiving can is made to contain an increased quantity of sliver, by means of a cylindrical plunger which falls at intervals into it. The sliver is also made to coil up regularly in the can in a compact form, without being at all stretched.

Roving.—By the process of drawing, the cotton wool has been formed into a loose porous cord, the fibres of which are arranged in parallel lines. This cord is much too thick to be spun into yarn, and it is too tender to be reduced in size by drawing merely: a slight twist is therefore put into it, and this, by condensing the fibres, allows the drawing to be proceeded with. This, in fact, is the commencement of spinning, which, in a cotton-mill, is little more than a combination of drawing and twisting, and it is called *roving*. The roving machine, which was introduced by Arkwright, resembled the drawing-frame. It consisted of two pairs of drawing-rollers, Fig. 649, for extending the slivers, of which two were generally doubled and united, and the sliver, after leaving the drawing-rollers, was received into a can, which was made to turn rapidly round; and this, by giving a slight twist to the sliver, formed the *roving*, and distributed it in a coil within the can, from which it was removed when full by a door left open as in the figure. The process was thus far successful; but it was necessary for the next operation that the roving should be wound upon bobbins, and this was done by girls, by the aid of a simple machine, called a *winding-block;* but in handling the delicate cord it was scarcely possible to avoid injuring it, so that the quality of the yarn suffered. This led to the introduction of the *Jack-frame* or *Jack-in-a-box*, in which the twist was given by the revolution of the can as in Fig. 650; but instead of being coiled up within it, the roving was wound upon a bobbin *b*, lying upon a carrier cylinder *c*, made to revolve by wheel-work, not shown in the figure, at such a rate

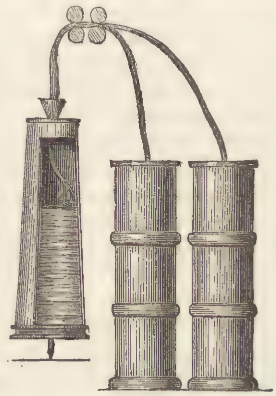


Fig. 649.

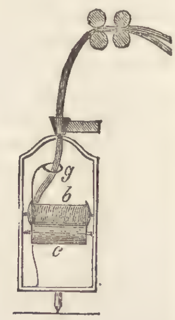


Fig. 650.

that its surface velocity corresponded with that of the front drawing-roller. A guide-wire *g* was made to move backwards and forwards in front of the bobbin, in order to distribute the roving equally upon it. The Jack-frame was superseded by the *bobbin-and-fly-frame*, which, after a large number of improvements and modification by various inventors, may now be considered as the roving-machine of the cotton manufacture. We will first endeavour to explain the principle of this very complex machine, and then to give the details of the mechanism by which it is carried out. The chief difficulty in this class of machines arose from the soft tender nature of the roving, and the nicety required to wind it on the bobbin at exactly the same rate that the front pair of rollers sent it forth.

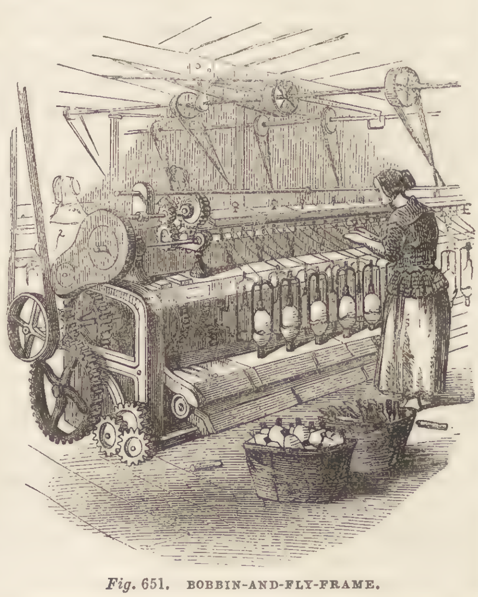


Fig. 651. BOBBIN-AND-FLY-FRAME.

The bobbin-and-fly-frame has to perform two essential operations: *first*, to twist or spin the sliver into a roving, and *secondly*, to wind the roving in a

regular and equable manner upon the bobbin. Fig. 651 is a pictorial view of a portion of the machine, which is of considerable length. The bobbins containing the sliver are mounted upon a shelf called a *creel;* from these bobbins the sliver is passed through a set of drawing-rollers mounted on a beam similar to those used in the drawing-frame. Before the sliver enters between the back pair of drawing-rollers, it is led through between two guides fixed upon a wooden bar, which has a very slow lateral transverse motion, so as to shift the sliver alternately to the right and left about three-quarters of an inch, in order to prevent the leather covering of the top rollers from being indented or grooved by the slivers passing constantly over the same line of surface. After leaving the front pair of rollers, the sliver is received by the spindles, which are arranged in two rows, for economy of space, each spindle in the back row standing opposite the interval between two spindles in the front row. One frame may contain 30, 60, and even 120 spindles. At the lower ends of the spindles are small bevel wheels, g', Fig. 652, driven by others, f', fixed on horizontal shafts which go from one end of the machine to the other; *g g*, Fig. 654, is the flyer or fly, one arm of which is made hollow, for the purpose of containing the roving, the other being a solid rod, the only use of which is to counterbalance the former, and prevent its flying off or getting loose upon the spindle, on the conical summit of which

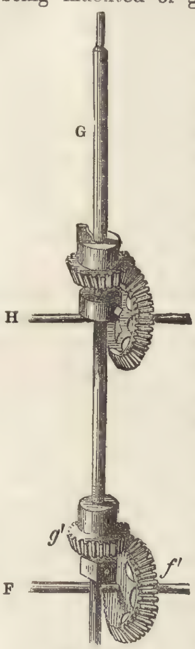


Fig. 652.

it is pressed after a full bobbin has been removed and an empty one put in its place. The bobbin, Fig. 655, is a simple wooden tube, upon which the roving is wound, so as to produce conical ends, as in Fig. 656, by shortening, after a certain period in the winding-on, the extent of the up-and-down motion of the bobbin, which is given in order to distribute the roving equally and compactly over the bobbin. This object is further assisted by the steel finger of the fly, Figs. 653, 654, over which the roving is twisted, and which winds it on the bobbin with a certain pressure. Now, supposing this system to be in motion, the bobbins on the creel give out the sliver to the rollers; these, after extending it by drawing, pass it down to the spindles, which by their rapid rotation twist or spin it into roving, which roving is then wound upon the bobbins which surround the spindles. It is evident that as the roving is always winding from the lower end of the flyer, it is necessary that the bobbins ascend and descend as they revolve, so that the roving be laid evenly and smoothly upon them. This rising and falling motion is produced by the gradual ascent and descent of the copping-board, on which the bobbins rest, by which means every coil of roving falls close to but not upon the former coil, thus disposing it regularly through all the length of the bobbins; and when the latter

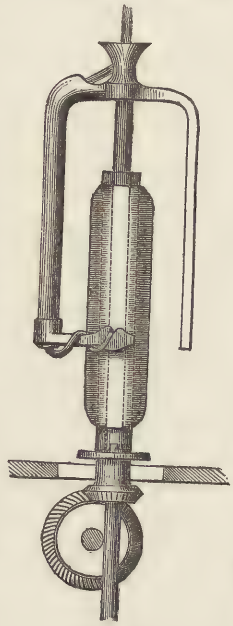


Fig. 653.

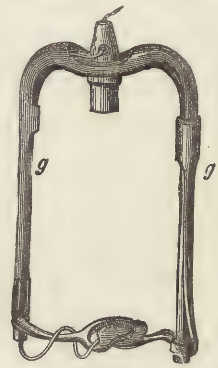


Fig. 654.

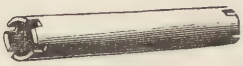


Fig. 655.


Fig. 656.

have descended to the lowest point, they gradually rise again, then fall, and so on, till they are filled, and renewed by the tenter-women, whose business it is to supply other bobbins, and to unite any of the rovings that may separate or break. Now it is evident that as the bobbins become filled with rovings, and the circumference of each bobbin increases, it requires to have a gradually decreasing velocity, or, in other words, it is necessary after each ascent and descent of the bobbin that its speed be made proportionally slower, in order that the quantity wound up in a given time or in any given number of revolutions may be the same; for unless this precaution be attended to, the roving would not be of the same quality throughout: it would be slightly thicker when the bobbin was nearly empty, and would go on diminishing in thickness as the bobbin became covered; and this stretching force, not having the equable action of the drawing-rollers, would injure the roving. This change in the velocity of the bobbin is produced in various ways; one of which is by means of two conical barrels, Fig. 657, of the same dimensions, but placed with the larger end of one opposite the smaller end of the other. One of these barrels, being driven with a uniform motion, communicates motion to the other by an endless band, which, by being shifted towards either extremity, varies the motion of the other barrel. The belt or strap remains equally tight in every part, for the one barrel increases in diameter exactly as much as the other decreases. From the second barrel motion is conveyed to the wheels which work the copping-bar. These alternate cones form an elegant method of changing the velocity

of motion when this is required to be gradually and uniformly accelerated or retarded. It is obvious that if the axis of one cone, A, Fig. 657, have a uniform motion, its surface must move with varying degrees of velocity; and if motion be communicated from the surface of A to that of B by means of the belt, such motion can be accelerated or retarded at pleasure by causing the belt to be moved along by means of a guide, or the motion may be kept constant if the guide be kept stationary.

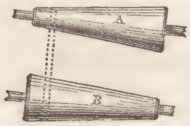


Fig. 657.

There are two sets of bobbin-and-fly-frames in common use, called the *coarse* and the *fine*, or the *first* and the *second roving-frames;* they are the same in principle, but the first has fewer spindles, and is fed with slivers from cans filled at the drawing-frame and placed at the back of the machine. The second roving-frame is fed with rovings, or, as they are sometimes called, *slubbings,* from bobbins filled at the first frame, and they are arranged on upright skewers fixed in a shelf or *creel,* placed behind the roller-beam. The roving from these bobbins passes through wire-eyes, to prevent it from being torn obliquely from the bobbins. In the coarse roving-frame the top of the machine behind the rollers is covered with a smooth plate, upon which the sliver glides from the cans towards the rollers. A rod stretches along over the machine, having at its extremity a guide for pulling the strap which drives the fast or steam-pulley: this rod, therefore, serves, when slid to the right or to the left, to put the machine into or to throw it out of gear, as the tenter requires in the course of the work, at whatever part of the frame she may happen to be.

These arrangements being understood, it will be seen that the twisting of the sliver is effected by the revolution of the spindle and fly, but the quantity of twist depends on the ratio between the surface-speed of the front delivering-roller, Fig. 651, and the revolutions of the spindle. The winding on of the twisted roving upon the bobbin is effected by giving to the bobbin such a velocity, that the difference between the motion of the surface of the bobbin and the motion of the delivering end at the arm of the flyer shall equal the surface-motion of the roller, or the supply of the sliver. The spindle and the bobbin being driven by different movements, and at different rates, the winding is effected either by making the bobbin revolve a little faster than the spindle, or the spindle faster than the bobbin. If, for example, the bobbin revolve 50 times while the spindle only revolves 40, 40 turns of the bobbin will have nothing to do with the winding; but there are ten turns of the bobbin above those of the fly which will perform the winding. Hence the 40 turns of the spindle produce twist, while the 50 turns of the bobbin produce 10 coils of the roving upon its barrel.

In the coarse bobbin-and-fly-frame it is usual to make the spindle revolve quicker than the bobbin, and in the fine frame to make it go slower. Dr. Ure places this matter in a clear light by the following examples:—"Suppose 45 inches of roving are to be wound upon a bobbin whose barrel is $4\frac{1}{2}$ inches in circumference: 10 turns will be required. Suppose these 45 inches to receive 30 turns of twist: the spindle and fly must give these 30 turns during the winding on of the roving. If the bobbin, therefore, be $1\frac{1}{2}$ inch in diameter, it must make 10 turns for the winding on, and 30 turns in following the spindle; in all, 40 revolutions. If the bobbin be 3 inches in diameter, or 9 in circumference, it must only make 5 turns to wind on the 45 inches: these 5 turns added to the 30 turns required for twist make 35 revolutions; and so on for any other dimensions of the bobbin. Hence, the number of turns of the bobbin, plus the number of turns of the spindle, is a quantity always inversely as the diameter of the bobbin. The motion of the bobbin and spindle is simultaneous, and in the same direction, with a difference varying more or less, according to the varying diameter of the bobbins. But suppose for a moment the spindle to be stationary: then the bobbin must turn with such a velocity that it will wind on the roving just as fast as the front rollers deliver it. This roving comes forward at a uniform rate; but the bobbin, continually increasing in diameter, should turn with a velocity uniformly retarded. Motion being given to the spindle, it is evident that when the winding is forward, as in the fine fly-frame, we must deduct from the rotation of the bobbin, required for winding on the roving, that of the spindle, required for the twist; for the circumference of the bobbin being $4\frac{1}{2}$ inches, 10 turns take up 45 inches. These 10 turns deducted from the 30 made by the spindle leave only 20 turns for the effective speed of the bobbin; or, if the circumference be 9 inches, 5 turns will take up the 45 inches, if the spindle be at rest, but if the spindle make 30 turns for twist, the effective speed of the bobbin will be $30 - 5 = 25$ turns. Hence, for the fine bobbin-and-fly-frame the number of turns of the spindle, minus the number of turns made by the bobbin in the same time, is a quantity inversely as the diameter of the bobbin. In the coarse frame the bobbin should move faster than the spindle, and its speed should go on diminishing; while in the fine frame the speed of the bobbin is less than that of the spindle, and it goes on progressively increasing.

In the coarse roving-frame the spindles revolve on an average 750 times per minute, turning off for each spindle 400 inches per minute, or $666\frac{3}{4}$ yards per hour. In the fine frame there is more twisting power, and this produces on an average $533\frac{3}{5}$ yards per hour. In the coarse frame the sliver is elongated from 4 to 6 times, the principal draught of $4\frac{1}{2}$ being between the front and middle rollers, and the remaining $1\frac{1}{2}$ between the middle and back rollers.

For fine spinnings the rovings are weighed on the bobbins by a quadrant beam, and distributed according to their respective weights into 5 numbered baskets. In some coarse spinning mills only one carding, one drawing, and one roving are employed for manufacturing the yarn used for the cheapest calico.

Such is a general account of the bobbin-and-fly frame. The reader who is interested in the study of

machinery, will find it an instructive exercise to make himself master of this complicated machine, which he will be able to do with the assistance of the accompanying steel engraving, and the following wood engravings and description, which have been prepared for the editor by his friend Mr. Hatcher.

We may consider that there are three things to be accomplished by this machine :—First, the roving has to be reduced in size, and consequently elongated. Secondly, it is to have a certain determinate number of twists given to each foot of its length. Thirdly, it must be coiled evenly round the bobbin, into the shape shown in Fig. 656.

The steel engraving, which we shall refer to as the plate, represents a back view of the mechanism of the bobbin-and-fly machine, and Figs. 658, 659, 660, represent a section and details of the same, similar letters being used in all cases to the same parts. Only a few of the spindles and rollers are drawn in the plate, so that the figure might be as clear as possible.

1st. To reduce the roving.—A strap from the engine shafting of the factory drives the main shaft B. This shaft by means of the spur-wheel 1, and the carrier-wheel 2, drives the wheel 3, and shaft C, which at its extremity carries a wheel 4, driving a larger wheel 5. This last is keyed on the shaft of the bottom front drawing rollers. It also carries a toothed wheel 6, which acts, by means of the carriers 7 and 8, on wheel 9, fixed on the shaft D of the lower back rollers, *d d d*. By changing the various wheels of this train, between Nos. 4 and 9, for which facilities are afforded in the construction of the machine, any relative degrees of velocity can be given to the front and back rollers, so as to draw or attenuate the roving just so much as may be required. Suppose, for instance, the back rollers were 1 inch in diameter, and made 60 turns per minute, and the front pair were $1\frac{1}{4}$ inch in diameter, and made 180 turns per minute; then the back pair will deliver out $3.14 \times 60 \times 1 = 188.4$ inches per minute, which by the greater speed of the front rollers will be lengthened to $3.14 \times 180 \times 1.25 = 706.5$ inches. So that the roving will have its length increased $3\frac{3}{4}$ times, and its thickness reduced in the same proportion.

2d. To give the roving thus drawn out a certian determinate degree of twist. The shaft B carries a bevel wheel 10, which by means of the wheel 11, shaft E, and wheels 12 and 13, drives the long horizontal shaft F F. This shaft extends along under the cast-iron beam *f f*, and carries a series of small bevelled wheels *f′ f′*, which drive the upright spindles G G G, by means of small wheels *g′ g′* keyed upon these spindles. See Fig. 652. The spindles revolve independently within the disks and collars of the bobbins, on the beam *h*, and at their tops they carry the flyers *g g g*. Hence the flyers derive their motion from the same shaft B, which gives movement to the drawing rollers, and therefore the number of revolutions made by the flyers in any given time, will always bear such a constant ratio to the speed of the drawing rollers, as the attendant may by his arrangement of the wheels 4, 5, 6, 7, 8, 9, have determined upon beforehand. If, therefore, in one minute, or while the front drawing rollers deliver out $706\frac{1}{2}$ inches of roving, the spindles with their flyers make 1,300 revolutions, the roving will have rather more than $1\frac{3}{4}$ twists in each inch of its length. This is the usual proportion for the first or coarse machine. We repeat, (as it is important to bear this in mind,) that the velocity of the spindles bears always a certain predetermined ratio to the delivering speed of the drawing rollers, and that therefore the twist which the roving receives is always the same, throughout the piece, that has been fixed upon at its commencement. The rate of winding on to the bobbin, or the varying actual rapidity of the whole machine, cannot alter this ratio between delivery and twist.

3d. The coiling of the twisted roving upon the bobbin. We must here consider how we should proceed to wind the roving, so as to produce an even bobbin or "cop" of the shape shown in Fig. 656, and with no overlapping or irregularity in the laying on of successive coils.

First, then, we have seen that the bobbin must be carried regularly up and down within the flyer, as the roving winds on, at such a speed that each turn may lie evenly by the side of the preceding one, neither overlapping nor leaving a vacant space. This motion of the bobbin or "traverse" must continue steadily upwards, till one layer has been put on from top to bottom of the coil; and must then be suddenly reversed and continued steadily downwards, till the second layer has been put on, then again reversed for the third layer, and so on. Secondly, as each successive layer increases the effective diameter of the bobbin, the speed of revolution of this bobbin must be altered after each layer is completed; so that the rate of taking up of the bobbin may remain the same, and its surface velocity be always equal to the rate of delivery of the front rollers. Now suppose the bobbin to be $1\frac{1}{4}$ inch in diameter, or just equal to the front drawing rollers, then while these are delivering off $706\frac{1}{2}$ inches of roving, the bobbin must move so as just to wind up this quantity, which will give evidently 180 entire coils. But while this $706\frac{1}{2}$ inches is being delivered off, the flyer (in order to give it the right amount of twist,) is making 1,300 revolutions. We want the winding-up action, which is equal to the difference between the speeds of the flyer and of the bobbin, to equal 180 turns in this time. Therefore the bobbin must revolve at such a speed as would carry it through $1300 + 180 = 1480$ revolutions, in the same time that the flyer is making 1300. Now if each layer of roving increase the diameter of the bobbin by $\frac{3}{10}$ths of an inch, then we shall have for the second layer of roving :—

Circumference of bobbin $= 3.14 \times (1.25 + .3) = 3.14 \times 1.55 = 4.867$. Therefore the number of turns to be made by the bobbin, to take up the second $706\frac{1}{2}$ inches of roving $= \frac{706\frac{1}{2}}{4.867} = 145$ nearly. So that while the flyer continues to revolve at a speed which would carry it through 1300 revolutions in one minute, the

bobbin must now revolve so as to make 1300 + 145 = 1445 turns. Similarly we find that for the third, fourth, and fifth layers, the bobbin must revolve at such a speed as would make the ratio of its velocity to that of the flyer, as 1423 : 1300, 1405 : 1300, 1391½ : 1300 respectively. These numbers express ratios of velocity only, not that such numbers of turns must be actually made by one and the other before the speed changes; for the speed must change directly each layer is completed, whatever be the number of turns in it. It will also be evident that as the diameters of the bobbins, and consequently the quantity of yarn contained in each coil increases, the traversing or up and down motion of the bobbins must be slower. Were it not so, as the bobbin revolves more slowly in proportion to its speed of traverse, the yarns, instead of being laid closely together, would form an open screw-like coil. Thirdly, as the full cop must have its ends tapered, as in Fig. 656, to prevent any risk of the rovings slipping off, it is clear that each successive traverse of the bobbin must be shorter than the one preceding. Fourthly, as the bobbin when full will only just enter within the flyer arms, the action of the machine must be stopped with certainty, directly it has filled a set of bobbins. We now proceed to describe how these requisite adjustments are attained.

First,—to produce the traverse motion. The bobbins rest on a long beam or inverted trough of iron *h*, termed the "copping bar," or "copping rail." This is not fixed in the machine, but is fitted with slides to the end frames Z Z, and with guides to the upright rods *y y*, so as to be capable of moving up and down, through a distance equal to the length of the bobbins. Its weight is partly counterpoised by masses of cast-iron, suspended from it by chains passing on the pulleys X X. The chains and weights are omitted in the figures, to avoid complexity, but their action will be readily understood. The spindles G G pass through this copping rail without touching it, so that the small disks on which the bobbins rest, which are made to revolve by the bevelled wheels fixed upon the long dotted shaft H, can continue to revolve while travelling up and down the spindles. The shaft C before mentioned as driving the rollers, carries a drum, 15, from which a strap passes to the tin-plate cone, 16; a wheel 17 on the shaft of this cone, drives, by a second spur-wheel 18, the shaft K, and this by the bevel-wheels 19, 20, turns the shaft L, carrying at its end the bevel-wheel 21. This last wheel is placed between two facing bevel-wheels 22, 23, and it is evident that when engaged with one of these it will drive the shaft M in one direction, when engaged with the other it will drive it in the contrary direction. The pinion 24, at the end of shaft M, works in the wheel 25 and drives the shaft N, which carries pinions 26, 26, working in racks, Fig. 658, fixed to the copping rail; so that when the shaft M is driven one way it causes the copping rail to rise, when driven the other way it draws the rail down. The copping-rail has attached to it a slot-piece *i*. In this slot, a pin projecting from the circular end of the sliding bar V, works, and this sliding bar when raised lifts the tumbling bob or loose weight T by the pin v^1; but as soon as the copping-rail has attained a certain height, (raising the tumbling bob as it goes,) this bob having come to the vertical position tumbles suddenly over to the left, and in so doing slides the bolt U to the left, which pulls the bevel-wheels 22, 23, also to the left, by the rod *u* attached to a loose collar connected with the wheels. This brings the wheel 23 into gear with

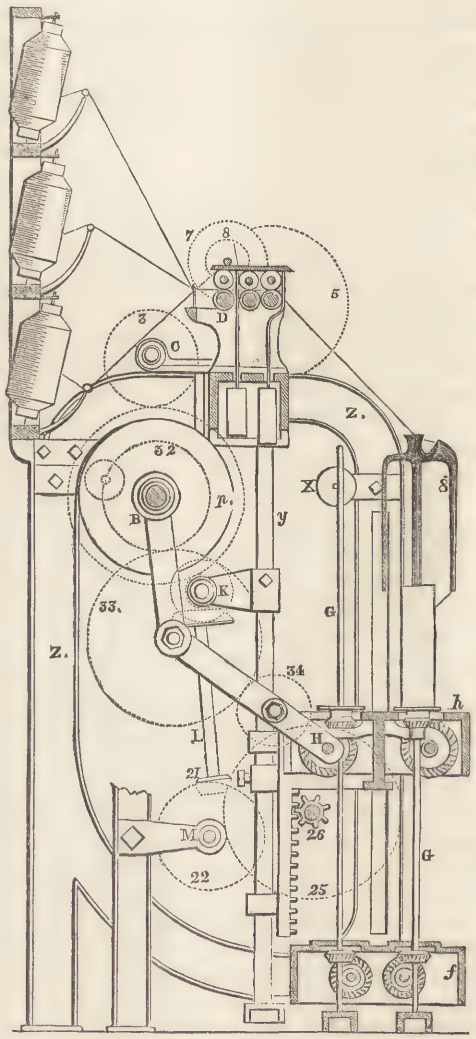
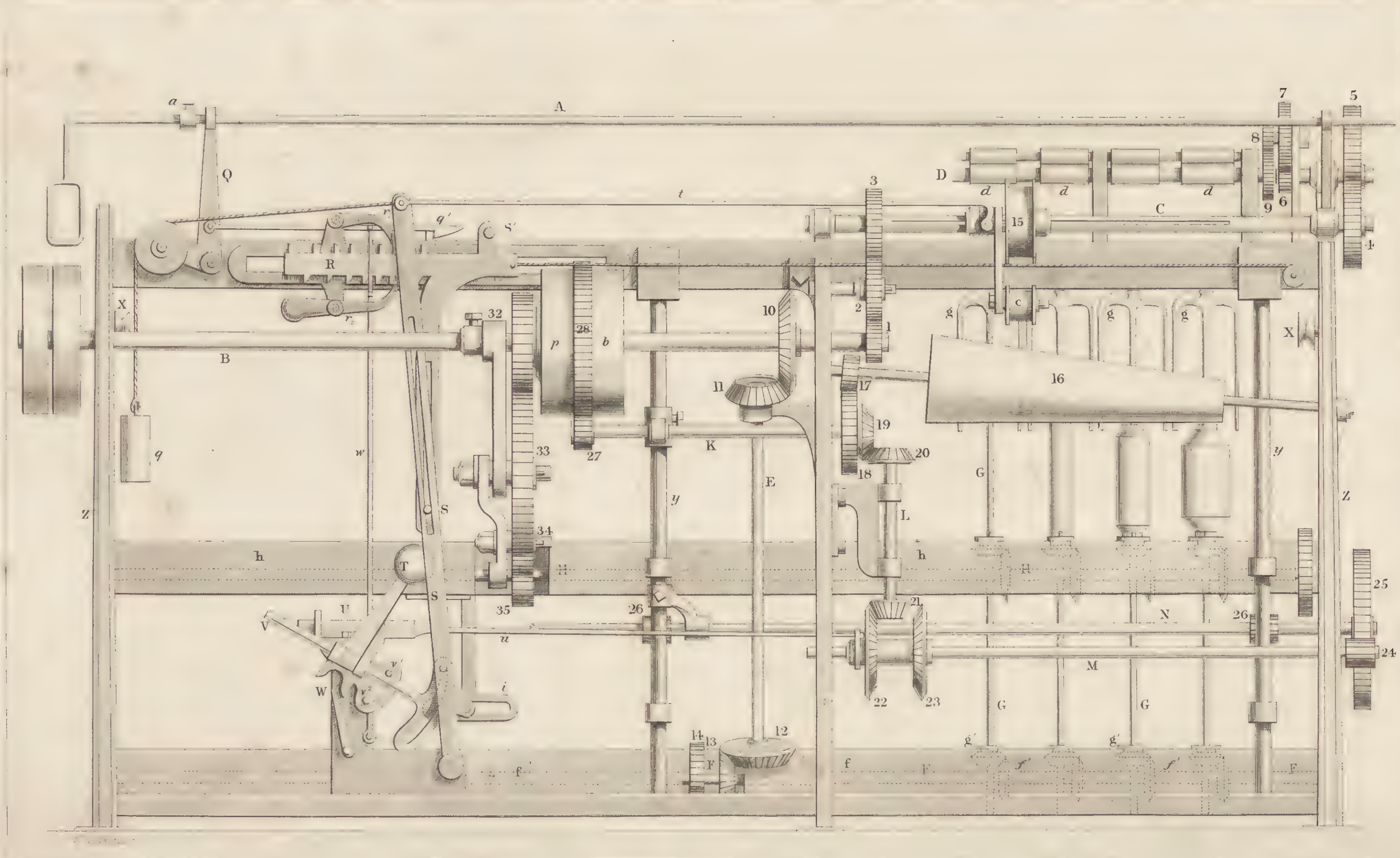


Fig. 658. SECTION OF THE BOBBIN-AND-FLY-FRAME.

pinion 21, and instantly reverses the motion of the shaft M. Consequently the copping-rail moves downwards, again raising the tumbling bob, but now of course by the sliding lever V bearing against the pin v^2, until the bob tumbles over to the right, and again reverses the motion of the rail by sliding the bevel-wheels to the right. The pins v^1 v^2 can be adjusted in their circular slot, so as to cause the bob to tumble over sooner, and thus lessen the traverse of the copping beam. The bevel-wheels 22, 23, are of course so keyed to the shaft M, that while moving



COTTON.
BACK VIEW OF HOULDSWORTH'S BOBBIN AND FLY MACHINE.

freely along it, they still continue to drive it. There is a pin fixed to the long lever S, which moves in the circular slot of the sliding level V, but this evidently does not in any way impede the up and down motion of this lever. The use of the pin will be seen hereafter.

We have now to explain, secondly, how the speed of the bobbin is altered at the completion of each traverse of the copping-beam, so as to equalise the winding on of the roving. We have before mentioned the tin plate cone 16, as driving the shaft K. This shaft carries a pinion 27, gearing into the wheel 28, turning in the centre of the box *p b*, of which the use will be shown hereafter. This wheel is connected with the wheel 32, but they both turn loosely on the main shaft B, and have no connexion with it. The wheel 32 drives the long shaft H, by means of the elbow-linked carrier-wheels 33 and 34. On referring to the section, Fig. 658, the use of this elbow-link will be apparent. The bobbins must continue to revolve as the copping-rail carries them up and down, and this is attained by means of the linking of the wheels 33, 34, 35 to 32, so that they remain in gearing while continually rising and falling with the rail. The shaft C is slotted, so that the pulley 15 can slide along it, and yet continue to turn with it; and it is evident that as the pulley slides along, and carries its strap towards the larger end of the cone, this cone will be driven more slowly as its diameter at the driving part is increased. So that while the pulley moves uniformly, it can be made to turn more and more slowly the cone and the train of shafting and wheels which eventually gives motion to the bobbins. A tightening pulley *c*, which rests against the strap, keeps it always tight enough to drive the cone. At the left hand of the plate is a double rack-piece R, the teeth of which are placed alternately on the top and bottom edges, and which is held by the catches r^1 r_2 from being pulled to the left by the weight *q*, acting on the top of the long lever S, and by the pin *s* working in its slot, upon the projecting arm of the rack-piece. When the work commences with empty bobbins, the rack-piece is pulled to the extreme right, so that the catches engage and hold it by the end teeth on the left hand. It will be seen that the lever S is connected by a rod *t* with the sliding pulley 15, so that any movement of the rack-piece to the left must be accompanied by a corresponding movement of the pulley to the left.

The tumbling bob T at its lower end terminates in a fork, embracing the end of the bell-crank lever W, so that when the bob falls over to the left, at the end of the first upward traverse of the copping-rail, the bell-crank lever is moved to the right, and the upright rod *w* connected with its short end is jerked down. In so doing, one of two pins at the upper end of this rod lifts the lower catch r_2 from the rack-piece, and this consequently slides to the left (dragging the pulley 15 with it), till its motion is arrested by the upper catch, engaging the next alternate notch of the rack. Here it rests while the copping-rail completes its downward motion, at the end of which the bob tumbles over to the right, and at the same time that it reverses this motion of the rail, also by the bell-crank lever W, and rod *w* strikes up the upper catch, and allows the rack to slide to the left, till it is caught by the lower catch. As the shaft K drives the bobbins, and also the pinions serving to raise and lower the copping-rail, therefore each escape of the rack, by shifting the band towards the large end of the cone, reduces the speed of the shaft K, and consequently both the speed of revolution of the bobbins and the speed with which the traverse of the bobbins is made; thus providing for the second change which was noticed, as becoming requisite on the progressive increase of diameter of the bobbins.

In this manner, the traverse of the bobbins, the decrease of their speed of rotation, and also of their speed of traverse have been accomplished. We have now to show, in the third place, how the diminution of the lengths of successive traverses is produced, so as to give to the cop its conical ends.

The sliding lever V is not fixed in its centre, but slides in a boss, so as to allow of its length being reduced by sliding the circular head nearer to the centre; the result of which would be, that a smaller extent of up-and-down motion of this lever would make the bob tumble over from one side to the other. When the piece of work is commenced, and the rack-piece placed as far as possible to the right, the long lever S is inclined as much as possible to the right, it being connected with the rack-piece by the pin *s* passing through this lever and the slotted arm of the rack-piece. In this state the sliding lever is pulled out from its boss as far as possible, and therefore the space through which it must be carried by the copping-rail, before it throws over the bob, is the greatest possible. But each successive escape of the rack-piece draws the lever S over to the left, and this pushes the sliding lever further and further through its boss, by a pin fixed to this lever S, and passing through the circular slot of lever V, so that each successive traverse is rendered shorter than the preceding one, and therefore each layer of yarn or roving is shorter at both ends than the one below it. The ends will thus be rendered conical, as shown in the figures.

In the fourth place, to guard against the over-winding of the cops, it will be observed that the long rod A carries a stirrup embracing the driving-band, so that by this rod the band can be pushed from the fast to the loose pulley, and the motion of the whole machine stopped. On this rod A there is a stop *a*, which can be adjusted to any position, and the upright Q, through which the rod passes, is one arm of a bell-crank lever, over the other arm of which the weight *q*, attached to the rack-piece, hangs; so that the weight would pull the arm Q over to the left, were it not kept upright by a spring-catch *q'*, locking over a small upright piece on the frame of the machine. But when the rack-piece comes to leave the last tooth of its rack, (the bobbins being then just full,) a pin on the upright *s'* lifts the catch *q'*, and the weight there-

fore pulls the arm Q over, sliding the long rod to the left, pushing the strap on to the loose pulley, and stopping the whole machine. This is done without any care of the *tenter;* but we observe that the long rod, extending as it does along the whole length of the machine, allows the tenter, at whatever part of the machine he may be, to stop its motion in a moment, and thus to check any mischief arising from derangements, to allow time for piecing broken rovings, or making other alterations.

The teeth of the racks are set closer together to the right than at the commencement of the rack. This is to accord with the diminishing ratio of the speed of the bobbin to that of the spindle, which is shown by our first calculation of these ratios. The slope of the cone is also duly adjusted, to give, in combination with the diminishing distances of the rack teeth, exactly the proper degree of reduction of speed to the shaft K. But these adjustments, though perfect for any particular kind of yarn, would require modification, when yarn of a smaller diameter, or greater degree of twist, is made. The adjustment for finer yarns is given by the pin *s*, sliding in the slot of the long lever S, by which the effective length of this lever can be increased, and therefore the amount of its motion about its centre for each escape of the rack diminished. As the sliding in of the sliding lever V, and therefore the amount of decrease of traverse and speed of the bobbins, after each layer of yarn, depend on the amount of motion of the long lever about its centre, we have thus the adjustment required for finer yarns. But the adjustment for different twist is made by means of the Equational box, or Differential pulley, *p*, *b*, and Figs. 659, 660. This box consists of two short cylinders of cast-iron, *p* and *b*, each enclosing a bevel wheel, 29, 31. Between the edges of these boxes is a spur-wheel, 28, carrying a third bevel-wheel, 30, mounted on an axis forming a radius of the spur-wheel. This third wheel gears into the two other bevel-wheels. Outside of the half-box *p*, and attached to it, is a spur-wheel, 32. The three bevel-wheels are exactly alike in diameter and number of teeth. The half-box *b*, with its wheel, is keyed to the shaft B, and turns with it, but the wheel 28, and the half-box *p* with its wheel, turn loosely on the shaft and independently of it. Now, if the wheel 28 be held still, and the shaft B is turned, it is evident that the middle bevel-wheel 30 will act merely as a carrier between 29 and 31, which will turn with the *same speed, but in opposite directions.* If 28 be turned round at the same speed as B, and in the same direction, then the middle wheel 30 has no tendency to revolve on its axis, but acts simply as a pin between 29 and 31, causing 31 to turn with the *same speed as* 29, *but in the same direction.* These are the extreme cases. The middle case is when 28 turns with half the speed of B, and in the same direction. In this case, 30 merely runs round on 31, and 31 *does not move at all.* Hence, therefore, all possible degrees of motion between absolute rest and a velocity equal that of shaft B, can be given to 31, and therefore to 32, by changes of velocity given to 28, between that of half the speed of the shaft B and that of the same speed as B. Now these changes of velocity in 28 are easily produced, by merely putting a larger or smaller pinion on the shaft K, in the place of the pinion 27. Therefore, as the wheel 32 joined to 31 drives the bobbins, their speed can be adjusted, by this simple change, to have any given ratio to that of the spindles and flyers, whatever be the velocity of these last. Now, if the speed of the flyers were doubled, so as to double the twist of the yarn, the speed of the bobbins must not be doubled also, but must be altered so as to leave the same difference as before between their speed and that of the flyers.[1]

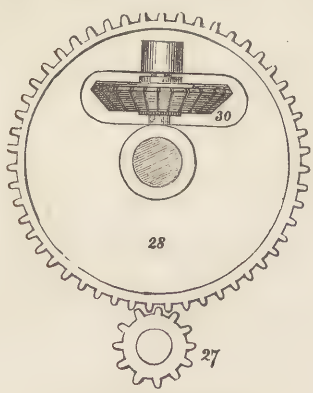


Fig. 659. CENTRE WHEEL OF EQUATIONAL BOX.

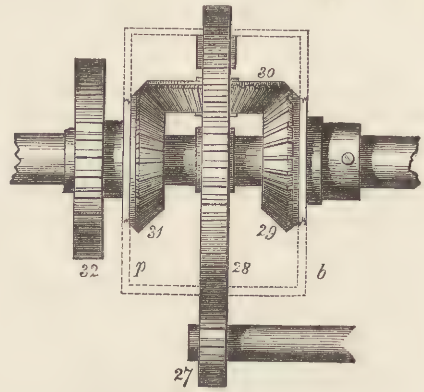


Fig. 660. DETAILS OF EQUATIONAL BOX.

Many of the minor details of the machine, such as the "spring fingers," for assisting the winding of the yarns, the form of the teeth of the bevel-wheels driving the spindles and bobbins, have been necessarily omitted, or only glanced at, in this description.

In fine spinning, two rovings are doubled and passed a second time through the roving frame, where they

(1) In numbers, this would stand thus. To give double the twist to 706½ inches of yarn, the flyer must make $1300 \times 2 = 2600$ revolutions in a minute. But the speed of the bobbin must not be double its former speed, for that would be $1480 \times 2 = 2960$ revolutions per minute, and the taking up in such case would be $2960 - 2600 = 360$ circumferences of the bobbin, or $360 \times 3.92 = 1411$ inches per minute. The *difference* between the speeds of the bobbin and of the flyer must remain the same, and therefore the bobbin must now make 2960—180 = 2780 turns per minute. This adjustment is readily made by means of the differential pulley. We may observe that this pulley (the invention of Mr. H. Houldsworth) seems to give the last degree of perfection to the admirable mechanism of the bobbin-and-fly machine.

receive a further degree of drawing and twist. In fine spinning the rovings are sometimes prepared at what is called the *stretching-frame,* which is a kind of mule-jenny; but the usual plan is to finish the rovings, that is, to spin them into yarn, at one of two machines, namely, the *throstle* and the *mule-jenny,* which are now to be described. The difference between these two machines may be thus briefly stated:—the mule having made a definite length of yarn, the operation of spinning is suspended while the yarn is being wound up upon bobbins or spindles. In the throstle, on the contrary, the yarn is both spun and wound up at the same time. Moreover, the throstle yarn, also called *water-twist* from having been produced at the *water-frame* as already noticed, is smooth and wiry, while the mule-yarn is soft and downy. Throstle yarn is usually employed for *warps* in heavy goods, such as fustians, cords, or for making sewing-thread; mule-yarn is used for the *weft* in coarse goods; and also for warp and weft in finer fabrics.

Water-twist or throstle-spinning.—In the bobbin-and-fly-frame, the roving is twisted only to such an extent as will give it sufficient strength to unwind from the bobbins upon which they are coiled; if they were much twisted, they would resist the action of the drawing rollers of the throstle or the mule. In these two machines, however, the torsion is so increased and the filaments so firmly united, that any further drawing would cause them to break across rather than draw out into downy ends.

The object of the throstle is to draw out the rovings into slender threads, at the same time that it twists them by the rotation of the spindles and flyers; the yarn thus produced is at the same time wound upon bobbins as in the bobbin-and-fly-frame, but with a much smaller outlay of mechanical contrivance, on account of the greater strength of the hard twisted throstle yarn. The throstle consists of two roller-beams, each provided with the usual three-fold set of drawing rollers, which, instead of being mounted in fours and sixes upon independent heads, are all coupled together in one range upon each side of the frame. The top rollers are as usual covered with leather, and the roving passes over a guide bar, to which a slight horizontal movement is communicated for the purpose of leading the roving over different points of the rollers, and thus preventing the leather from being chafed by constant pressure on one spot. The machine is usually made double, a row of bobbins, spindles, &c. occupying each side of the frame. The bobbins, filled with rovings, are placed upright upon skewers fixed in shelves in the middle of the frame or *creel.* There are usually from 70 to 150 spindles on each side of the throstle, and they are set from $2\frac{1}{2}$ to 3 inches apart. The spindles on both sides are driven in common, by means of bands from the long horizontal tin cylinder, which extends the whole length of the machine; this cylinder is seen in Fig. 661, and also in section *C,* Fig. 662. On quitting the last pair of rollers, each roving is guided by a little ring or notch of smooth glass let into the frame at *e,* towards the spindles, which revolve with great rapidity, producing by the motion of their flyers a low musical hum, which is supposed to have given the name to this machine.

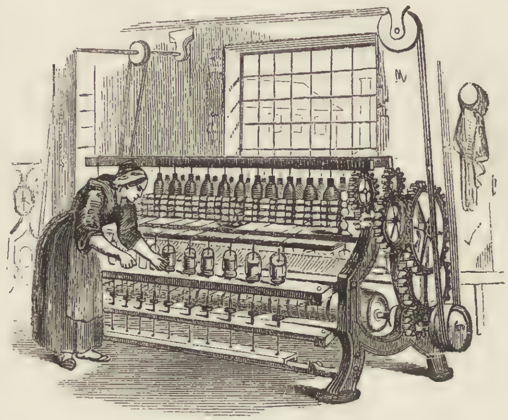


Fig. 661. THE THROSTLE.

The roving, which may now be called *yarn,* passes through an eyelet formed at the end of one of the arms of the flyer, and thus guides the yarn to the bobbin, which revolves round the spindle axis in the middle, between the two prongs of the flyer. Immediately over the spindle, is an eyelet of wire, which serves as a guide to the roving, which is led once or twice round the arm of the fly, and then passed through one of its hooked extremities. The yarn is wound upon the bobbin by a curious

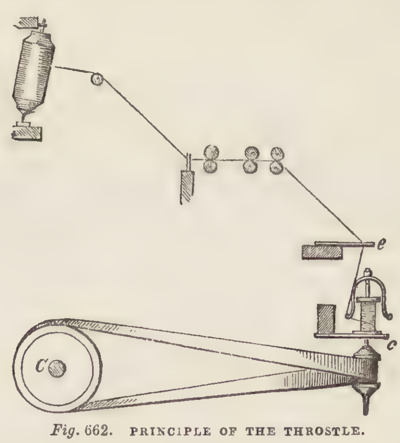


Fig. 662. PRINCIPLE OF THE THROSTLE.

contrivance. The bobbin fits very loosely upon the spindle, and rests with one end upon the copping-rail, *c.* The bobbin is not connected with the spindle, except by the thread of yarn which has to be wound; so that as soon as the flyer is set spinning the thread drags the bobbin after it, and makes it follow the motion of the spindle and fly; but the weight of the bobbin and its friction on the copping-rail, which is promoted by covering the end with coarse cloth, causes it to hang back; and thus the double purpose is served of keeping the thread stretched, and winding it on the bobbin much more slowly than the flyer revolves. The yarn is equally

distributed on the bobbin, by a slow up-and-down motion of the copping-rail.

These effects are similar to those produced in the bobbin-and-fly-frame, but in the throstle they are attained by simpler means. In the former machine, the bobbin and the spindle were made to revolve by distinct mechanical movements; in the throstle, the bobbin is made to revolve by the pull of the yarn, which is now sufficiently strong for the purpose; the roving in the bobbin-and-fly frame could not bear such a strain.

The throstle is tended by one young woman and an assistant; they have the care of 140 to 300 spindles in two double frames, and their duties are to mend broken threads, to remove the full bobbins, and to substitute empty ones. This task is called *doffing*, and it occasions on an average the loss of half-an-hour a-day with the common throstle. The full bobbins are collected and carried away in a kind of hamper, Fig. 663, made of buffalo leather, and hence called a *buffalo*. The bobbin of compressed roving, laid on with the spring presser, Fig. 654, will last on the throstle-frame from 4 to 5 days.

Fig. 663.

The quantity of yarn turned off is about 24 hanks per spindle of 30's twist in 69 hours. In spinning 32's, the front rollers of the common throstle make 64 revolutions per minute, and the spindles, 4,500. It is stated that in spinning 24's, a speed of 80 turns per minute has been given to the front rollers, and 7,000 turns to the spindle.

In some factories, the upper surface of the rollers is wiped and cleaned from loose filaments of cotton, by means of a travelling cone, made of wood, covered with flannel; it is about a foot long, with a base 4 inches in diameter. It is laid loosely on the rollers, and travels by friction in about 17 minutes, from one end of the roller-beam to the other in the direction of its taper end. After completing a journey, it is removed, and a clean one substituted for it.

Several new forms of throstle have been introduced, but our limited space will not allow us to do more than mention the names of the American or Danforth throstle, Gore's patent throstle spindle, Montgomery's patent spindle, &c.

Mule Spinning.—The object of this operation is to convert the rovings into yarn, and to wind the yarn thus produced upon spindles. This is accomplished by means of a complicated machine called the *mule* or the *mule-jenny*, which consists of four distinct members:—1. Of drawing rollers, consisting, as before, of a number of fluted portions, each of which operates on two parallel threads; 2. A movable carriage, the length of which is equal to that of the roller beam, and containing as many spindles as there are threads to be spun. This carriage admits of being drawn forward through a space of 5 feet in front of the roller beam, and its wheels move upon iron rails, placed at right angles to the roller beam; 3. The head-stock, or machinery which drives the different parts. This is usually placed in advance of the roller beam towards the middle of its length, thus dividing the range of threads into two portions; 4. The creel-frame, erected behind the roller beam, for holding the bobbins of rovings which are to be spun.

Fig. 664 is a cross section of this machine, showing the spinning parts; the carriage is shown by full lines in the position nearest the roller beam, and by dotted lines in the position when fully run out. A is a triple set of drawing rollers, working in heads fixed upon the roller beam, B; C is the creel for holding the roving bobbins in 3, and sometimes 4 rows, one over and behind another. To lessen the friction in unwinding the roving, the lower ends of the bobbin skewers stand in *creel-steps*, or small conical cups of glazed pottery. The creel and roller beam are

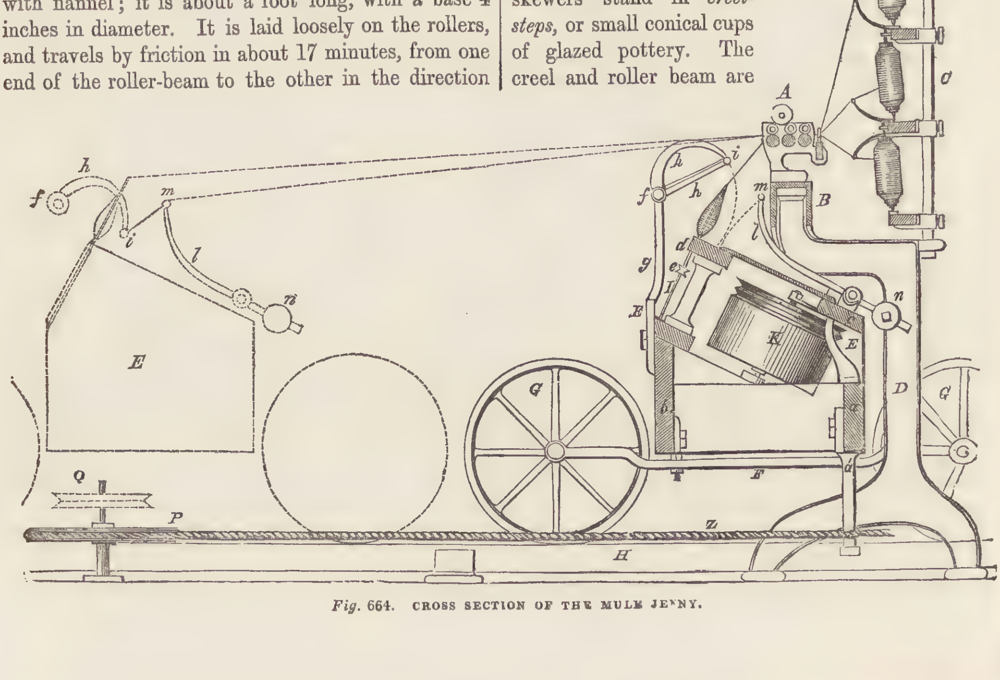


Fig. 664. CROSS SECTION OF THE MULE JENNY.

supported by frame pieces of cast-iron, as at D. E E is the carriage to which are attached 3 or 4 horizontal bars, F, which rest upon the axis of the wheels, G G. The wheels run upon the railway, H. The carriage is formed of two long planks, *a*, *b*, extending through its whole length, and barred with cross pieces of wood or iron, made fast by screws; there are also diagonal braces, and other contrivances to prevent warping or vibration. Upon these planks is built a frame-work, *c*, *d*, in front of which are fixed the top bushes and bottom steps of the spindles, I. The spindles are set in an inclined position, sloping towards the roller beam, so that in revolving the threads may be twisted round their points without being wound upon their surfaces during the coming out of the carriage; *e* are little pulleys called wharves, fixed upon the under part of the spindles, each at a different height, throughout a range of 8 or 16 adjoining spindles. K is one of a series of drum cylinders, usually made of tin plate, each furnished with two grooves round the upper end for receiving the driving bands. Their smooth sides receive and work the moving bands or cords of two ranges, containing from 16 to 32 spindles. The uppermost cord impels the first spindles of the adjoining two rows; the second cord moves the second spindles of the same ranges, and so on in succession; *f* is a long, slender iron shaft, lying in the bearings, *g*, over the carriage from end to end, and provided with small arms, *hh*, called the *fallers*. These bear the *fäller wire*, which serves to depress all the threads from the points of the spindles, as in the dotted lines under *i*, and to bring them upon a level with the bottom of the cop in the act of winding on. The wire being then gradually raised, the thread is duly distributed upon the cop. To assist the spinner in applying the faller wire so as to coil on the yarn with regularity, there is another wire called the *counterfaller;* this consists of lever arms, *l*, with the fulcrum attached to the framework: these arms bear at their points, *m*, a wire which extends horizontally, like the faller, from end to end, but beneath the surface level of the threads. On the other ends of these levers are weights, *n*, which cause the wire *m* to rise so as to balance the threads after they are depressed by the faller wire, *i*, and to straighten them when loose. The carriage is drawn out by a rope, Z, passing round 2 horizontal pulleys, only one of which is shown in Fig. 664, and this is in front of the mule, at the spot to which the carriage comes on completing its stretch: this pulley, P, turns freely upon an upright stud in the floor, and is looped round a bolt, *a'*, attached to the carriage, E. The spindles receive their whirling motion all the time that they go out and in with the carriage by means of a distinct band passing round a twist pulley, provided with 6 grooves of progressively increasing diameter, calculated to vary the whirling velocity of the spindles. This pulley is situated in the head-stock at the back of the mule, not shown in the figure, but an endless band proceeding from it passes over a guide pulley, and then over the top grooves of the drums, K, thus driving all the drums on the right hand side of the carriage; the band then returns round their second grooves, and passes to the drums at the left hand side of the carriage. After driving all the drums there, it returns to the middle of the machine, and passes over guide pulleys to the horizontal pulley, Q, which revolves freely on the same upright bolt with the rope pulley, P, and from thence proceeds to the twist pulley. By this contrivance the band is always of the same length, whether the carriage be in or out, and the drums, K, which work the spindles, are thus continued in motion, at whatever point of its course the carriage may happen to be. Fig. 665 will convey

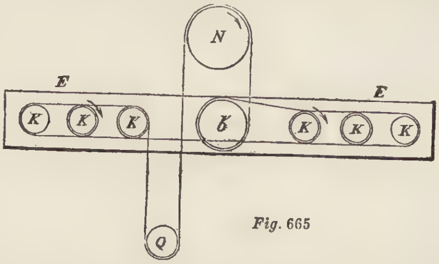


Fig. 665

a general idea of the working of these band coils. N is the twist pulley, Q the end pulley, K the carriage drums, and E E the carriage. It will be seen that the carriage can be moved backwards and forwards between the fixed centres of the pulleys N and Q, while the coils of the band continue to move round the drums. It must be remembered, however, that the revolving parts do not lie in one plane as in Fig. 665, but in different planes, the band being conducted over guide pulleys, wherever a change of plane occurs. There are many other parts of this machine which cannot be described without numerous elaborate engravings; so that the reader who desires a fuller account ought to consult Dr. Ure's work.

The above slight sketch will enable the reader to understand the general working of this machine. While the rollers are delivering the drawn out roving, the steam-engine moves out the carriage with a speed somewhat greater than that of the front rollers; this excess of velocity is called the *gain* of the carriage, and its object is to render the yarn level, by allowing thicker parts of the yarn to be extended while they and the thinner parts are being twisted. While the carriage is being thus moved out, the spindles revolve with moderate velocity, and twist the roving into yarn; but when the carriage has moved out about 45 or 50 inches, according to the fineness of the work, the machine is so contrived that the rollers stop and cease to deliver thread. The carriage is then slowly moved to the end of its course, while the velocity of the spindles is nearly doubled, thereby giving such additional twist (called the *stretching* or the *second draw*) to the yarn as may suit it for the particular purpose for which it is intended; a greater twist being given for warp than for weft, and for bobbinet and book muslin yarns, than for the yarns of softer fabrics. The carriage being drawn out to the end of its course, thereby stretching the threads to the full extent which they will bear without breaking, it is stopped, but the spindles continue to revolve till

the requisite quantity of twist is given, and this is regulated by the twist-wheel having completed a certain number of turns. A finger fastened upon the twist-wheel disengages a catch whereby the driving strap is allowed to pass to the loose pulley, and the whole machinery stands still. The spinner then turns a winch-handle acting on a pulley, which moves all the spindle drums at once, and thus causes the spindles to turn a short space backwards, for the purpose of taking off the slant coils from the upper ends of the spindles, and to prepare for distributing the 54 or 56 inches length of yarn just spun properly upon them. This reversing of the spindles is called *backing off.* The spinner then seizes the faller rod with his left hand, and gives the faller wire such a depression as to bear down all the threads before it to a level with the bottom of the cop of yarns which is being formed round the spindle. While the left hand of the spinner is thus employed in the delicate operation of depressing the faller wire, his right hand is slowly turning the handle of the pulley in communication with the spindles, so as to give them a whirling motion in the right direction; at the same time the spinner applies his knee to the carriage, and pushes it in at the proper degree of speed required to supply yarn to the spindles as they wind it on the cop. "Three simultaneous movements must be here very delicately and dextrously performed by the mule-spinner; first, the regulation of the faller or guide wire, continually varying in obliquity; secondly, the rotation of the spindles, perhaps 1,000 in number, at a measured speed; and thirdly, the pushing in of the carriage at such a rate precisely as to supply yarn no faster than the spindles take it up. In fine spinning upon a mule, where nearly 1,000 threads are spun at once, of almost invisible tenuity, the skill and tact required in the operator deserve no little admiration, and are well entitled to a most liberal recompense. In the process of winding on, so as not to break the threads, and in coiling them into the shapely conoid or cop, the talents of the spinner are peculiarly displayed. As the carriage approaches to its primary position near to the roller-beam, he allows the faller wire to rise slowly to its natural elevation, whereby the threads once more coil slantingly up to the top of the spindle, and are thus ready to cooperate in the twisting and extension of another stretch of the mule. Having pushed the carriage home, the spinner immediately sets the mule again in gear with the driving shaft, by transferring the strap from the loose to the fast steam pulley, and thus commences the same beautiful train of operations. It is during the few instants after the carriage starts that the lively little piecers are seen skipping from point to point to mend the broken threads. Whenever it has receded a foot or two from the delivering rollers, the possibility of piecing the yarn being at an end, the children have an interval for repose or recreation, which, in fine spinning at least, is three times longer than the period of employment. The spinner, likewise, has nothing to do till after the completion of the fresh range of threads, when he once more *backs off* the slanting coil, and winds on the *stretch.*" By winding successive portions of thread upon the spindle, the cop, Fig. 666, is formed, which, when sufficiently large, is slid off the spindle, and is sent into the market as *cop-yarn.* A very large portion, however, especially that intended to be dyed or exported, is unwound from the cops upon reels, and then made up into skeins or hanks. Considerable skill is required in giving the cop such a shape as may facilitate the winding off, either in the shuttle or upon the reel. The foundation of the cop, which is first formed, is a double cone, *a, d, b, c;* upon the upper part of this the cone is *built* upwards, so as to form a cylindrical middle part, *a, b, e, f.*

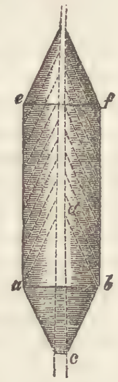


Fig. 666.

One man attends to two mules, guiding in the carriage of one mule by hand, while the carriage of the other is being moved out by the steam engine. The children who join the broken threads are called *piecers* or *pieceners.* There is, also, a child called a *scavenger,* whose business it is to collect all the loose or waste cotton, called *fly,* which lies on the floor, or hangs about the machinery. This is chiefly used in cleaning the machinery. It is calculated that the waste of material from the different machines in spinning cotton amounts to $1\frac{1}{2}$ oz. per lb., or nearly $\frac{1}{10}$th. It is the duty of the piecer to join the broken ends of the threads as the carriage moves from the upright frame. The breaking of the threads depends, in some degree, on the temperature, and the state of the atmosphere. Sometimes, during an east wind, the threads break faster than the piecers can join them; and it is not improbable that the rapid whirling of so many thousand pieces of machinery produces in very dry weather a large amount of electricity, which may prevent the proper spinning of the fibres. At such times it is not uncommon to keep the atmosphere of the room moist by jets of steam, and to maintain a temperature of from 68° to 76°. Indeed, fine yarn cannot well be spun at a lower temperature.

It will be seen by the above details, that considerable skill is required on the part of the spinner in the management of the mule. The demand for this kind of skilled labour has enabled the spinners to command high wages, and as prosperity requires a larger amount of self-knowledge and self-control than adversity, so the well-paid spinners, intoxicated by success, frequently committed the foolish acts of drunken men. As the quality of the yarn depended upon the care and attention of the spinner, it was thought impossible to execute by machinery that which required mind. This led the spinners on many occasions to league together for the purpose of compelling their masters to grant such wages as they chose to demand, and to accept such an amount of labour as they chose to give. Thus the mill-owners were subject to great disarrangement of business, and consequent loss, from the frequent "turn-outs" of the

spinners, by which not only were their assistants thrown out of employ, but also the persons employed in the preparatory processes of carding, roving, &c., all of whom were, in the majority of cases, compelled reluctantly to cease from working, as the product of their labour was not required so long as the spinners remained idle. The spinners being provided with ample means, consequent on high wages, were able to continue the "strikes" for long periods of time. Their past successes led them to suppose that they alone were capable of directing and controlling the movements of the mule-jenny, the value of which, if it had any in their eyes, depended upon the amount of skill which they themselves brought to bear upon it; they thought that they were necessary to the mule, not that the mule was necessary to them. They could not rise to the reflection that the amount of inventive thought, highly-trained mechanical skill, and well-applied science, which had been brought to bear upon this machine, from the moment when the apparently fortuitous circumstance of the upsetting of a domestic spinning-wheel suggested the invention to a man of genius, were still at work, the more unweariedly and the more incessantly as the spinners were the more refractory and the more troublesome to their employers. Many attempts had been made to produce a self-acting mule, but without success, until Mr. Roberts, of the celebrated firm of Sharp & Roberts, machine-makers, succeeded completely in the invention of the self-acting mule, or the *iron-man*, as it is sometimes called in Lancashire. This extraordinary machine not only does the work of the spinning mule without the assistance or attendance of any one except the little piecer, but does it in a more perfect and complete manner, and produces a larger quantity of yarn. The cops, also, are firmer, and of better shape, and contain a larger quantity of yarn than cops of equal size wound by the spinner; and in weaving, the superior firmness of the cop allows the loom to be worked at greater speed, whereby cloth of a superior quality is produced in greater quantity. As mechanics become better educated, they will understand the principles which must regulate the demand and supply of labour: the employed have to consult the interest of the employer as much as their own, and unless there is a mutual interchange of good offices, both must suffer. "Strikes" and "turn-outs" have in many, if not most of the useful arts, led to the invention of highly ingenious machines, which have superseded labour, or, at least, skilled labour, so that the workmen who combine against their employers eventually injure themselves, and even annihilate their own occupation. It was only a few weeks ago that the Editor witnessed the completely successful experiment of producing by machinery an important part of an article in most extensive use, which had hitherto been supplied entirely by hand, and to which self-acting machinery was thought inapplicable. The workmen, although (or because) in the receipt of good wages, had long been very troublesome to their employers. We regret exceedingly the thought that they will not have the opportunity of being so much longer.

Reeling.—The yarn which is wound by the throstle upon bobbins, and by the mule is formed into cops, is, if intended for warps, wound off into measured lengths of 840 yards, called hanks. This is done by means of a six-sided reel, 1½ yard in circumference, mounted in a carriage which carries the spindles or skewers that bear the bobbins or cops; the carriage

Fig. 667. REEL FOR WINDING AND COUNTING HANKS.

has a slow traverse motion, parallel to the axis of the reel, for properly distributing the thread upon its surface. The woman who attends to the machine, watches the revolutions, until a check is struck, which is done when the wheel has completed 80 turns, and as the circumference of the wheel is 1½ yard diameter, a *ley* or *rap* of 120 yards is thus formed; 7 of these raps make a hank of 840 yards. The hanks having been tied round with a string to separate and distinguish them, one of the arms which keep the reel distended is loosened, and the hanks are slid off by hand, and a fresh set is wound as before. The size of the yarn is ascertained by weighing the hanks in a balance called a quadrant. Tables are also published for readily ascertaining the number of hanks to the pound, but the following rule is practically correct:—Divide 1,000 grains by the number of grains in a ley, and the quotient will give the number of hanks to the pound. This rule is founded on the fact that a ley is 1-7th of a hank, and that 1,000 grains is equal to 1-7th of a pound. The usual average number of hanks to the pound is, for coarse spinning, from 10 to 40, but for some purposes, such as candle-wicks, coarse counterpanes, &c., such low numbers as 2 hanks to the pound are manufactured. Yarn of from 4 to 6 hanks is often exported. The highest number usually obtained in fine spinning is 300, but the Editor saw at Mr. Houldsworth's mill, at Manchester, yarn of which 460 hanks were required to make a pound weight.[1] This yarn is a beautiful, hard, cylindrical cord, of wonderful fineness, and has been sold for 20 guineas

(1) A specimen of British lace, made from yarn of the number 600, is exhibited in the Great Exhibition; and the Editor has just been informed that yarn of the number 800 has been produced.

or upwards per pound,—a remarkable example of the effect of well-directed industry in increasing the value of raw material. A pound of the best sea-island cotton is worth at the highest price 5*s.* per pound: when manufactured into yarn of the number 460, the value of this pound of cotton is 420*s.*, its value having been increased 84 times. This yarn was produced by Mr. Houldsworth for the purpose of being woven into muslin for a dress for Her Majesty, in order to show the capabilities of the British manufacture in producing a yarn far superior to any of the boasted yarns of the Hindoo spinner. Such yarn is not, of course, commonly made, but if a demand for it were to arise, it could be supplied at a gradually diminishing cost to the producer, and consequently to the consumer also.

Each size of yarn is sent into the market in cubical packages of 5 or 10 pounds weight. These packages are closely compressed, so as to diminish the bulk of the yarn, and preserve it from injury. The packages are made up in a simple but ingenious machine, called a bundling-press, Figs. 668, 669. It consists of a strong frame of cast-iron, situated beneath a wooden table BB, on one side of which is piled the yarn ready to be packed, and on the other the papers and twine used for making up the bundles. The bundles of yarn are seen in Fig. 668 between two upright sets of flat bars or rulers *b b*, Fig. 669, and resting upon a piece of wood upon the iron press-plate

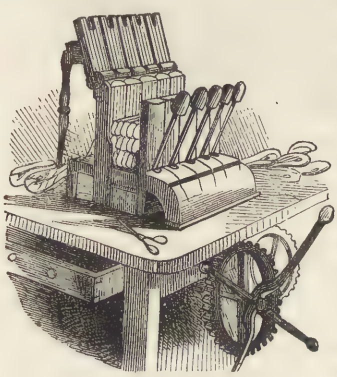


Fig. 668. BUNDLING-PRESS.

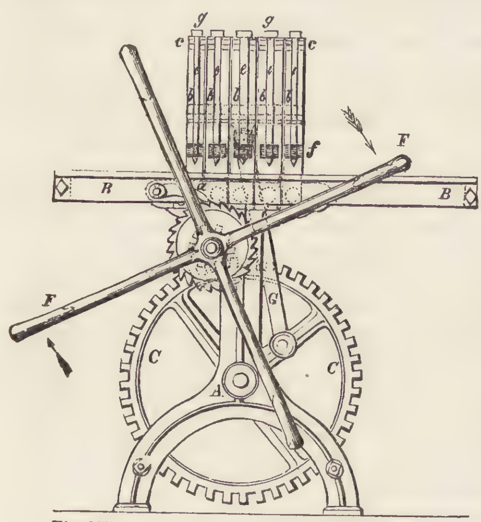


Fig. 669. WORKING PARTS OF BUNDLING PRESS.

of the machine. In this wood are grooves for laying the packthread or twine, the loose ends of which are seen in Fig. 668 hanging down between the spaces of the five upright flat bars. The hanks having been slightly twisted and neatly folded together, and put into their places, as in the figure, the top rails *g g* are lowered, and the key-rods pushed into the slits of the rails. The man then turns the iron cross F, which acts upon a pinion C and a ratchet-wheel furnished with a click *a* to prevent the wheel from flying back: upon one of the radial arms of this wheel is a connecting-rod G, the upper end of which is joined by the press-plate, which must therefore move upwards when the wheel is turned round. The plate is furnished with two guide-bars, which move between flanges within the frames, and is thus carried up vertically. When the bundle is thus sufficiently compressed, the man binds the twine round it, then pushes the click out of the ratchet-tooth, and the elastic rebound of the cotton drives down the press-plate.

Gassing.—Fine yarns are disfigured by a number of loose divergent fibres, which require to be removed in order to give them that level compact appearance which is required in the manufacture of bobbin-net-lace-thread, and for hosiery. The removal of these loose fibres without injury to the yarn would seem at first view a hopeless undertaking; but it is easily and successfully effected by one of those clever devices which so often excite our admiration in studying the processes of the useful arts. By passing the yarn rapidly through the flame of a gas-jet, the loose filaments are completely burnt off, the yarn is improved both in appearance and value, while it is diminished in weight, for a yarn of No. 90 thus becomes No. 95, making a difference of 5 hanks per pound by the operation of gassing.

The gassing-room is usually situated in the upper part of the mill, where the air is not likely to be disturbed. A large number of jets of coal-gas are burning on frames that occupy the length of the room: the jets are about 12 inches apart, and above each is a little hood or chimney. On entering the room, the smell of burnt cotton is perceived, and on approaching one of the frames, each flame is seen to be crossed in two or three directions by a delicate line apparently at rest; but on following the course of this thread, it is seen to proceed from one bobbin *d d*, Fig. 670, which is rapidly spinning round, and to pass through the flame to another bobbin or cone *b b*, which is also kept in rapid motion by being pressed against the tin drum *c* which is moved by means of the strap *a*. The intermediate thread is led over pulleys backwards and forwards through the flame, which thus singes off the loose fibres, converting them into a reddish kind of dust, which is very injurious, if inhaled. The rapid motion of the yarn through the flame prevents it from being consumed. On finally emerging from the flame, it is cleaned by passing over a brush. It then passes through a small hole or notch in a piece of brass, which is ingeniously arranged to detect any knot or foul point in the yarn. The hole is so small that there is but just room for the yarn to pass: if, there-

fore, a knot or other impediment occur in it, the piece of brass is depressed, and this is connected with mechanism which suddenly turns the gas-flame aside, and lifts the bobbin away from the rotating barrel. The yarn thus remains at rest, and the tenter-woman mends the defect, and sets the bobbin in motion again. Thus no time is lost, for while the defective thread stops, all the others are going on as usual.

Fig. 670. "GASSING" THE THREAD.

DOUBLING AND TWISTING (*Manufacture of Thread*).—The word *thread* in non-technical language is usually applied to a thin narrow line of any fibrous material; but the manufacturer limits the term to that compound cord produced by doubling and twisting two or more single yarns. There are various kinds of thread, such as *bobbin-net-lace-thread*, *stocking-thread*, *sewing-thread*, &c. Lace-thread, which is made of fine numbers of yarn, usually from No. 140 to No. 350, consists of two yarns twisted together; sewing-thread usually consists of three or more single yarns twisted into one; stocking-thread varies in the number of its yarns according to the object of the manufacturer.

The doubling and twisting mill, or *thread-frame*, is a machine resembling in many points the throstle of the cotton-spinner already described. The doubling is effected by spindles and flyers, and the twist is usually given to the doubled yarns in an opposite direction to the twist of the individual yarns. The machine has one pair of rollers for the purpose of delivering the yarns at a measured rate to the twisting spindles, to ensure the proper degree of tension, and to promote an equable torsion. The thread, after being twisted, is wound upon bobbins mounted loosely on spindles, the bobbins being dragged round by the thread, as in the throstle-frame: the copping-rail on which the bobbins are placed has the usual up-and-down motion for ensuring the equable distribution of the thread over them.

Fig. 671 will further illustrate these arrangements. As the yarns are unwound from the bobbins or cops,

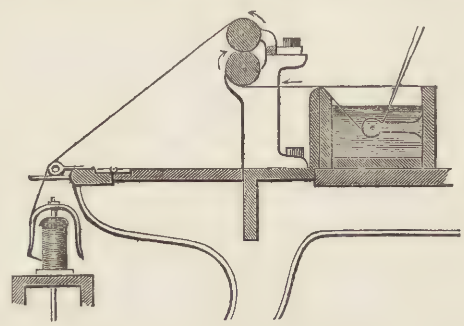


Fig. 671. SECTION OF THREAD-FRAME.

they are led across a glass rod, and passed into a leaden trough filled with water or a weak solution of starch; this wetting allowing the lines of yarn to twist into a more solid thread. On emerging from the trough, the yarns, 2, 3, 4, or 6 in number, according to the required size of the thread, are guided over a roller, which lays them parallel, or nearly so, and they are then passed down to the eyelet at the extremity of the flyer, the rapid revolutions of which twist them into a solid cord or thread, which is then wound upon the bobbin.

The thread is next made up into hanks for dyeing or bleaching, as may be required; and when dyed or bleached, it is wound upon bobbins for the purpose of *balling* or *reeling*. The process of forming the thread into balls or reels is performed with wonderful celerity in the following manner. A young woman is seated at a kind of turning-lathe, with the bobbin of thread mounted upon a spindle above her head: she seizes the end of the thread, and attaches it to a rod of steel, sets this spinning, and in an instant a ball of cotton appears at the end of the rod. The rotation is stopped, a blue ticket is inserted at the end, a further quantity of thread wound to secure the ticket, and the ball is finished. The size of the ball is regulated with great accuracy by the eye. The number of balls to the pound varies from 16 to 600; and the young woman being told to produce a certain number to the pound, makes a few, weighs them until she has got the exact size by weight; after this she relies entirely upon her eye, and so accurate is her judgment, that the variation of the balls in weight is very trifling. The cotton is also wound upon reels with surprising celerity; the steel finger which delivers the thread from the bobbin being guided to and fro to distribute it equally along the barrel of the reel. The quantity here also is judged of by eye, and varies from 30 to 300 yards in each reel. As each reel is filled, the broken end of the thread is inserted in a notch, which the winder cuts for the purpose. Reeling is not such rapid work as balling, but is still sufficiently swift to prevent the eye from following the motion of the thread. The chief delay in both cases arises from the breaking of the thread, which, during the writer's visit, occurred rather often.

The reels are placed on end in a kind of shallow

drawer, and little children cut out and paste on the labels. These labels are printed on sheets, and the back of each sheet is covered with gum, like the postage stamps. The children stamp out the labels with a circular punch, wet the back of each against the tongue, and then press the wetted side against the end of the reel. Some idea may be formed of the extent of this business from the fact that a sheet containing 144 labels, printed in blue and gold, and glazed, and then covered on the back with a layer of gum, is sold for one penny. The smallest bronzed cotton bobbin-labels are sold as low as one half-penny per gross.

The balls of cotton are tied up in small flat bundles, each containing a quarter of a pound; the proper number is counted out, folded up in paper, and tied into a bundle, with the remarkable speed and precision which is attained only by long practice: four of these quarters are next tied up into pound parcels, which, after being labelled, are ready for the wholesale market.

The amount of cotton-wool imported into England in 1850 amounted to 678,810,587 lbs., of which 104,389,504 lbs. were exported, leaving a quantity for home consumption amounting to 574,421,083 lbs.[1] By far the greater part of this supply came from the United States of America. For some years past, the cotton-wool imported from foreign possessions paid an import duty of 2*s.* 11*d.* per cwt.; that from British possessions paid only 4*d.* per cwt. From the 22d of March, 1845, this duty was wholly repealed.

In 1850, the prices of cotton-wool at Liverpool were as follows:—Sea Islands cotton-wool from 12*d.* to 15*d.* per lb.; Uplands, $3\frac{3}{8}d.$ to $4\frac{1}{8}d.$; Orleans, $6\frac{3}{4}d.$ to $8\frac{1}{4}d.$; Egyptian, $7\frac{1}{2}d.$ to $8\frac{5}{8}d.$; Common West Indian, 6*d.*; Surat and Madras, $4\frac{1}{2}d.$ to $5\frac{5}{8}d.$

The quantity of cotton-yarn spun in England and Scotland in 1850 was as follows:—

	lbs.
In England	488,151,914
In Scotland	31,011,131
Total	519,163,045

The quantity of cotton-yarn exported from England in 1850 amounted to 120,222,488 lbs. Of this quantity the principal portions were distributed as follows:—

	lbs.
The Hanse Towns, &c.	44,636,589
Holland	19,768,287
Russia	4,211,063
India	15,362,082
China	2,425,010
Sardinia, Tuscany, &c.	3,944,154
Belgium	2,439,283

The remainder was sent in much smaller quantities to various parts of the world.

The quantity of cotton-thread exported in 1850 amounted to 3,062,503 lbs.

The total weight of yarn in manufactured cotton-goods exported from England in 1850 amounted to 348,556,257 lbs; the total value of which was 28,771,592*l.*

(1) 1849	Imported	754,741,275 lbs.
	Exported	100,452,668
	Retained for home consumption	654,288,607

COUPLINGS. When a line of shafting is of greater length than can be cast or forged in one continuous line, the ends of the shafts are joined together by what are called *couplings;* they are also used to disconnect parts of the gearing beyond a certain point of the line, and also to connect and disconnect particular machines.

It does not appear, at first view, to be difficult to unite or couple the ends of two shafts, so as to make them act as if they were one piece; nor would it be difficult if machinery could be made perfectly true, if their parts were not liable to wear and tear, and the supports not liable to settlement.

The most simple method of coupling, is to make the ends of the shafts square, and to use a square coupling box, whose interior dimensions shall correspond exactly to those of the ends of the shaft, so that when the ends are in their places in the box and one shaft is set in motion, the other revolves with it. If it be required to transmit motion along one shaft only, the box can be slipped back on one shaft, and the one which is disengaged can be removed either for the purposes of repair, or for giving rest to machinery, &c. which is driven by the shaft.

In coupling square ends, the motion will of course be smooth and continuous in proportion as the shafts are in a straight line, and the ends fit accurately. Accuracy in these respects is difficult to attain in large machinery, and if attained in the first instance, it would not continue long, on account of the wearing of the different parts, and the settlement of the supports. Hence the shaft in some part of its revolution is lifted off its bearings, thereby producing an unsteady motion, and much straining and wearing of the couplings, which in their turn suffer and increase the evil.

In small machinery which can be executed with care, and where the wear is comparatively small, the square coupling box can be used; but it is seldom employed in mill-work. An excellent coupling is a cylindrical box, in which two pins, at right angles to each other, are inserted through the box into the shafts to connect them together. This joint can be made with greater precision and at less expense than the square coupling, because the ends of the shafts and the box can be turned in the lathe, and thus be made to fit with great precision. There is no wear in this kind except in the holes and pins: the latter are easily replaced, but as they cannot be made to fit so accurately as at first, this form of coupling is not much used for heavy shafting.

Couplings are more easily applied when each shaft has two bearings; but it often happens that each shaft has but one bearing, in which case, a neat and compact mode of coupling, adapted to all kinds of shafting, large or small, is the *half-lap joint.* The ends of the shafts are made semi-cylindrical, and fitted together so that the tongue of one fits into the recess of the other, thus completing the cylindrical form; the joint is then covered with a thimble or ring, and is secured to it by a key. This coupling is

accurate and durable, but expensive; it is much used in the better kind of millwright work.

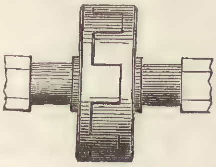


Fig. 672.

For shafts with two bearings, a method of coupling is shown in Fig. 672. The shafts are terminated with circular heads, one having teeth, and the other corresponding indentations to receive them. Should any slight settlement of the building, or other cause, depress one of the bearings or raise another, so as to throw the two shafts out of a straight line, these joints admit of a slight bending, and will, notwithstanding this, steadily communicate the motion of one shaft to the other.

A coupling first used by Mr. Murray of Leeds, for connecting a long line of shafts which carry a heavy strain, is shown in Figs. 673, 674. Should the shafts be out of line, this coupling acts as a sort of universal joint. A and B are the two shafts united; C D their necks or collars, which lie in the bearings; the ends projecting beyond these, have two boxes E F fixed on them by a square with wedges, or by a

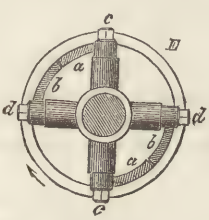


Fig. 673.

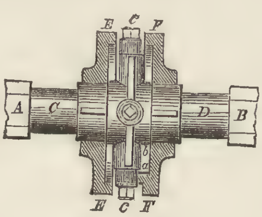


Fig. 674.

round part with a fillet; one box, E, has a piece projecting from the inside of it on each side, and extending into the other box as in *a a*, Fig. 673, which shows the inside of the coupling. The box F has two similar pieces projecting from it at *b b*, into the box E. Within the box, the iron cross *c c*, *d d* has screws fixed into the end of the arms by which motion is communicated. Now when the shaft A, and the box E are turned round in the direction of the arrows, the pieces *a a* act against the screws *c c* of the cross, and cause them to revolve, at the same time that the other two screws *d d*, at the other arms of the cross, press against the pieces *b b*, which belong to the box F, and the shaft B, thus causing them to rotate also. The cross is quite detached in the boxes, and thus acts as a universal joint to communicate the motion of one to the other; the screws *c c*, *dd*, at the end of the cross, are only used in order that the acting points may be of smooth steel, and thus diminish friction. This method of coupling requires a bearing at each end of every shaft.

Mr. Murray also introduced another method of coupling, which requires only one bearing for every length of shaft. A, B, Fig. 675, are the two shafts, each with a pivot at the end; these pivots are fitted into the coupling box, C D E, bored inside to receive the ends of the shafts, and turned outside with a neck D D, working in the bearing. The shafts A, B, are connected with the coupling-piece D, at C and E, by means of a cross-key *l m* put through each shaft, the ends being received in notches inside the coupling-piece. The shafts do not fit tight in the pieces E and C, but only in the pivots *a b*, by which means, they have a little freedom of motion

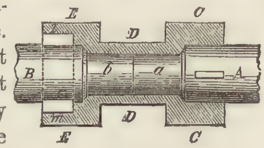


Fig. 675.

without straining the bearing in which D runs, because it is only the short coupling-piece which is received therein, so that a slight deviation from the straight line does not produce an injurious strain.

Dr. Hooke's universal joint, Fig. 676, is a method applicable to light machinery, of uniting shafts which are inclined to each other. The two shafts A and B, within the bearings C and D, terminate in a semicircle or fork; G is a circular iron ring within 4 pins or pivots *a a a*, on its circumference, which fit into holes in the ends of the forks, thus uniting them together, and allowing freedom of motion. In this way, a rotatory motion may be conveyed from

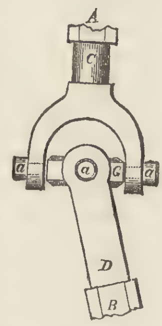


Fig. 676.

the shaft to another when they have a considerable inclination, but if the angle formed by the two shafts be more than 15 degrees, it is advisable to use bevelled wheels, because when so much inclined, the universal joint works with great friction and irregularity of motion. These joints may be constructed with 4 pins, fastened at right angles upon the circumference of a hoop or a solid ball.

There is a form of coupling called *friction coupling*, in which the connexion depends simply on the contact of the surfaces. It is not applicable to heavy machinery, but in certain circumstances it is more advantageous than any other method, because by its means the machinery can be limited so as just to have sufficient friction to carry on the work with the ordinary resistance, but so little beyond it that should an accident happen or any thing get entangled with the machinery, the additional resistance will stop that part, while the other part continues to rotate, thus preventing damage to the work under operation, and injury to the workman. Fig. 677, is an example of friction coupling. One shaft, A, has a circular plate O cast on the end, fitting into a loose box on the end of the other shaft B; *b b* is a collar of leather, fitting

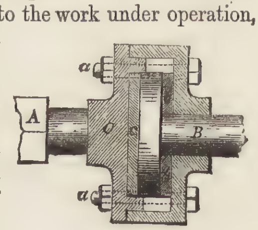


Fig. 677.

within the enlarged end of the shaft B, so that when the nuts *a a* are screwed up, it causes the box to press against the collar of leather, and by its friction puts the shaft in motion. The collar of

leather is sometimes placed at the end of the shaft, as at *c*.

For various methods of engaging and disengaging machinery, see GEERING.

COURT PLASTER. A black sticking-plaster, made by taking ℥ss of benzoin and ℥vj of rectified spirit, dissolving and straining them; then taking ℥j of isinglass and Oss of hot water, and dissolving and straining them separately from the former. The two are then mixed and set aside to cool, when a jelly is formed, which is to be warmed and brushed ten or twelve times over a piece of black silk, stretched smoothly. When this is dry, a finish is given by a solution of ℥iv of Chian turpentine in ℥vj of tincture of benzoin. Court plaster is made more adhesive by the addition of caoutchouc.

CRANBERRIES. The fruit of a species of *vaccinium*, a family which produces the Whortleberry and the Bilberry. Cranberries are very abundant in North America, and in the northern parts of Russia. They are also found in mossy bogs in different parts of Scotland. The Russian cranberries are esteemed the best. The fruit is red and about the size of a currant, growing on a diminutive plant, in boggy situations. It makes an agreeable preserve. Our importation of cranberries amounts to thirty or thirty-five thousand gallons annually.

CRANE. A machine for lifting heavy weights. Until within a period comparatively recent, the construction of cranes was of a very rude and inartificial character; but the necessity which has arisen, as a consequence of the advance of arts and manufactures, for lifting and transporting with ease and rapidity ponderous machinery, stones, timber, and vast bales of goods, has led to the construction of instruments far more efficient in their operation, and at the same time more skilfully and artificially arranged.

The more important parts of a crane are known by the names following:—The *crane-post* or *stalk* (B C Fig. 680) is the upright post of wood or iron, on which the crane turns. The *jib* is the horizontal or inclined beam, from the end of which the weight hangs (A C Fig. 680). The *stay* is the piece which supports the jib from underneath (Figs. 679 and 680), this in iron cranes is usually replaced by *tension-bars*, (A B, Fig. 680), of wrought-iron, placed above the jib. The *barrel* is the drum or roller around which the chain is coiled.

Cranes for landing-wharfs and quays are now usually made of iron. The crane-post is a hollow pillar of cast-iron, stepped at its foot into a cross-shaped framing of cast-iron, and passing through a similar framing at the level of the ground. The extremities of the crosses, Fig. 678, are bolted together through a mass of masonry, so as to render it impossible for the crane to move or overset. The jib may be of cast-iron, in the form of a simple pillar, cross-shaped in section, or if the crane has to carry a heavy weight, it may assume the form of a deep framing, or of two such framings bolted together side by side. The jib is frequently made of a pillar of wood, supported at its ends in strong sockets of cast-iron. The tension-bars of wrought-iron at the top, form eyes to encircle the pivot of the sheave, or are keyed or pinned to the upper socket of the jib. At the bottom they are keyed or bolted to a framing of cast-iron, which carries the wheel-work, and which turns on a pin at the top of the crane-post. The lower part of this framing turns on a collar at the foot of the crane-post. The foot of the jib is connected to this collar, either resting entirely upon it or upon a wheel running on a rail of iron let into the masonry. The latter plan, as it throws less strain on the crane-post, is generally used with heavy cranes.

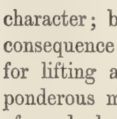


Fig. 678.

The wheel-work depends for its strength and the number of its wheels on the weights to be raised. It has been found that an ordinary labourer cannot work well for any length of time against a pressure of more than 15 lbs. at the level of his chest; so that whatever be the weight to be raised, the average stress on the winch-handle must be reduced, by the wheels and pinions, to this pressure for each labourer intended to work at the handles. The winch-handles are about 18 inches in radius, and a good height for their centres from the ground is 3 feet or 3 feet 2 inches.

A brief examination of the mode of application to a simple case of the principles which regulate the construction of cranes, will enable our readers to apply those principles to other and more complex instances.

Fig. 679 is a sketch of a $1\frac{1}{2}$-ton wharf crane, constructed by Messrs. Lloyd, Foster & Co. of Wednesbury. Fig. 678, is a plan of its foundation, and Fig. 680, a diagram of its principal parts, to show the distribution and resolution of the strains.

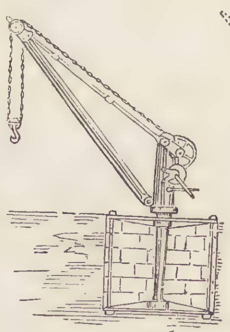


Fig. 679.

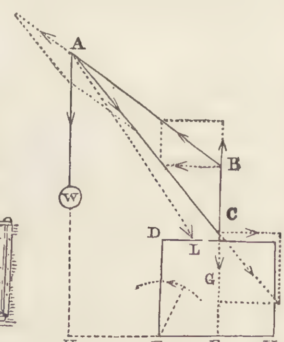


Fig. 680.

Beginning with the chain or rope, we find that the strength of chains of medium substance varies as the square of the diameter of the bars from which they are made. A chain with plain short links made of one-inch iron, should bear a weight of 32 tons, and a similar chain with studded links, nearly 40 tons. A rope of 3 inches circumference will bear about 2 tons, and the strength of ropes increases as the squares of their circumference. But neither ropes nor chains should be worked with more than one half of the weights thus given.

The total strain produced by the load and its suspending chain and blocks, (if such be used,) upon the end of the jib, may be resolved by the parallelogram of pressures (See CARPENTRY) into two forces, one straining the tension bars, and the other compressing the jib. If this be done as in Fig. 680, the force on the jib will be found to be about $4\frac{3}{4}$ tons, and the strain on the tension-bars about $3\frac{3}{4}$ tons, with a suspended weight W of $1\frac{1}{2}$ tons.

The strength of the tension-bars varies directly as their sectional area. A bar of good English iron one square inch in section, will break with about 20 to 25 tons of longitudinal strain. But as it is permanently elongated with half this weight, it must never in practice be exposed to more than $\frac{2}{5}$ths of it, say 10 tons per square inch of section.

The jib may be regarded as a pillar exposed to compression in the direction of its length. The strength of such a pillar was found by Mr. Hodgkinson to vary[1] nearly directly as the fourth power of its diameter, and inversely as the square of its length. The following rule has been given for finding the diameter of the column to bear a certain pressure :—

"Multiply the square of the length, in feet, by the load to be borne, in pounds. Divide by 10 times the modulus of elasticity given in Mr. Barlow's tables for the material of the column, reducing this modulus to its value for feet by dividing by 12^3 or 1728. The quotient is the fourth power of the side of a square pillar which will bear the pressure. If the pillar is to be round, multiply the quotient by 1.7, and then extract the fourth root. The result is the diameter of a round pillar."[2] Thus, in the case of Fig. 680, if the jib had been a round pillar of Riga fir, the modulus of elasticity of a mean specimen of which is, in Mr. Barlow's tables, 145,000, we have, since $4\frac{3}{4}$ tons $= 10{,}640$ pounds, and the jib is about $14\frac{1}{4}$ feet long :—

$$\frac{\overline{14.25}|^2 \times 10640}{\frac{145000}{1728} \times 10} = \frac{203.06 \times 10640}{839} = 294.$$

Therefore, if the jib were to be square, its side must be $\sqrt[4]{294} = 4\frac{1}{4}$ inches nearly.

If the jib were to be round, its diameter would be $\sqrt[4]{1.7 \times 294} = 4\frac{3}{4}$ inches.

The ends may have their diameters lessened by from 1-6th to 1-7th, so as to give the jib somewhat of a spindle shape, without diminishing its strength. The ends should not be rounded, but should be cut quite square, and be made to abut very evenly on the bottoms of the cast-iron sockets into which they fit. Experiments have shown that by rounding the ends of a pillar its strength is diminished to one-third of what it would be with the ends flat.

The values of the modulus of elasticity[3] found by Mr. Barlow's experiments, are to be regarded as applicable only to really fine specimens of the various materials. Due allowance must in practice be made for middling or faulty specimens.

The strain of the tension-bars and the thrust of the jib evidently tend to break the crane-post across just above the ground. Each of these oblique forces may be resolved (as in Fig. 680) into two others, one horizontal, and tending directly to break the post across, the other vertical, and having no tendency to produce fracture. The crane-post may be regarded as a hollow beam, supported at its two ends B and F, and bearing at an intermediate point C a weight equal to the sum of the resolved horizontal forces. These in our figure amount to about 3 tons and $2\frac{3}{4}$ tons.

The resistance to rupture of a solid cylinder supported at both ends and loaded in the middle, is determined by the equation, $W = \frac{\pi S c^3}{4a}$; where $W =$ breaking-weight, $\pi = 3.1416$, $S =$ modulus of rupture of the given material, to be taken from Barlow's or other book on the strength of materials, c is the radius, and a the length of the cylinder, all dimensions being taken in inches. Also the strength of a hollow cylinder bears the same ratio to that of a solid cylinder of the same material, as the difference between the fourth powers of the outer and the inner diameters, divided by the outer diameter of the hollow cylinder, bears to the cube of the diameter of the solid cylinder.[4] The weight which any beam will bear when placed at its middle, is to the weight which it will bear at any other point, as the square of half the length of the beam is to the product of the distances of the point of suspension from the ends of the beam. These results give the breaking-weights. The working-weights in practice should never exceed one-half of these amounts.

Figs. 679 and 680 show the manner in which the foot of the crane is embedded, as it were, in a solid block of masonry. It is evident that on the sufficiency of this block to resist the tendency to overturn, produced by the weight of the jib and its suspended load, depends the whole stability of the structure. To ascertain the sufficiency of the block for this purpose :—Since the whole system tends to overturn on the angle E, we measure from this angle the moments of the two opposing weights, which are here, the block of masonry with the body of the crane, and the projecting jib with its load W. Therefore we have, by the equality of moments,[5] calling G the

(1) The formula for the breaking weight of a cast-iron solid column is $W = 44.16 \frac{D^{3.6}}{L^{1.7}}$; where D is the diameter, in inches, and L the length, in feet; W being the weight in tons. This is for columns whose lengths exceed 25 times their diameter.

(2) Glynn's Treatise on Cranes, published in Weale's Rudimentary Series.

(3) The following are values of the modulus of elasticity for some materials commonly used for crane-jibs :—

Red pine	230,000	Barlow
Riga fir (mean)	145,000	,,
Norway spar	182,200	,,
Oak, English	181,400	,,
,, Canadian..........................	268,600	,,
Cast-iron (highest value)	2,290,770,	Fairbairn
,, (lowest value)	1,197,450	,,

(4) See Moseley's "Mechanical Principles of Engineering," p.560.

(5) The principle of the equality of moments will be explained in the article MECHANICS. See also Tomlinson's "Treatise on Mechanics," published in Weale's Rudimentary Series.

weight of the block of masonry, C the weight of the crane, and ω the weight of the jib:—

$$(C + G) \times EF = (W + \omega) \times EH;$$
$$\therefore \; C + G = \frac{(W + \omega) \times EH}{EF}.$$

Whence, C being known, the required weight of G necessary to prevent overturning with a given weight W, may be found. The actual weight of the block should in practice be three or four times as great as the result thus deduced.

It is evident that if the jib, instead of resting against the crane-post, bore against a circular rail let into the masonry, as shown by the dotted jib in Fig. 680, less strain would be thrown on the crane-post. This is commonly done in cranes intended to lift very heavy weights.

The journals or bearings of the axles should be from $1\frac{1}{2}$ to 2 times their diameters in length, to avoid cutting. Their diameters must be determined by their required power to resist the torsion of the wheels. The resistance to torsion varies directly as the cube of the diameter, and inversely as the length of the rod strained. It is stated that a force of 120 lbs. acting on a winch-handle of 18 inches radius, does not practically twist an axle 2 feet long and $1\frac{1}{2}$ inch in diameter.

The journal of the crane-barrel has to bear the transverse strain of the weight. The rule given for determining the strength of axles so strained, is to make them proportional to the cube root of the stress to be borne in hundredweights, if of cast-iron, or proportional to the cube root of $\frac{9}{14}$ths of this stress if of wrought-iron. Thus, if a journal has to bear $1\frac{1}{2}$ ton or 30 cwt., its diameter should be $\sqrt[3]{30} = 3\frac{1}{10}$ inches, if of cast-iron, or $\sqrt[3]{\frac{9}{14} \times 30} = 2\frac{5}{8}$ inches, if of wrought-iron.

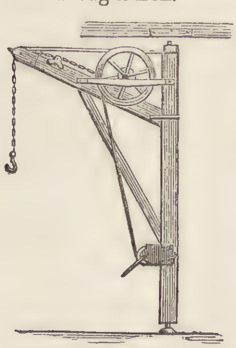


Fig. 681. GOODS CRANE.

Fig. 681 shows a form of crane used for unloading light goods and packages. The power is communicated from the winch-drum by a rope, which, as it uncoils from the wheel above, winds up the chain on the barrel.

Fig. 682 is a sketch of a form of steam crane used at the Camden Town Railway Station. A steam-engine keeps the shafting at the top with its several driving-wheels in motion. When the man pulls the check-rope, he lifts the crane-barrel about one axle, and raises the wheel of the barrel up, to press against the driving wheel above. The friction between the two wheels, increased as it is at pleasure by the man below, suffices to turn the crane-barrel and lift the weight. If the rope be slackened so as to lower the crane-barrel a little, it clears the driving-wheel, and yet does not drop into its bed, where it would rest immovable. In this position the weight descends freely, or the chain can be uncoiled. The driving-wheel is not vertically over the crane-wheel, so that the two coming obliquely into contact, are pressed together with more force.

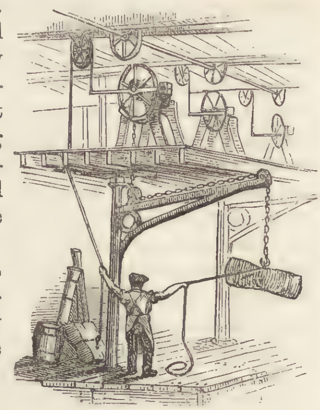


Fig. 682. STEAM CRANE.

Fig. 683 is a sketch of the traversing-crane now much used in large buildings, timber, and stone-yards. The whole framing traverses longitudinally on rails by means of a winch and toothed wheels. If both windlasses are turned at once, it is evident the weight will be raised. If one be unwound with the same speed that the other winds the chain, the weight will neither rise nor fall, but simply traverses towards the winding side. The action of this crane is sufficiently explicit without any detailed description.

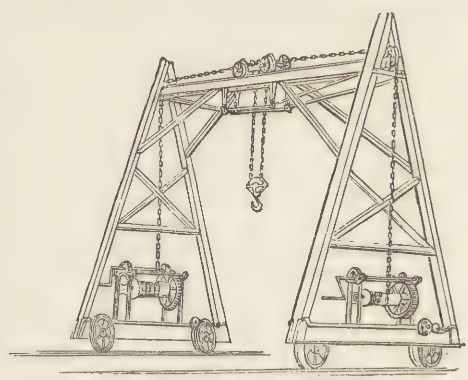


Fig. 683. TRAVERSING CRANE.

At Newcastle-on-Tyne, Glasgow, Liverpool, and some other places, the pressure of a head of water acting upon a moveable piston has been employed to lift weights, by means of a crane arranged somewhat as shown in the sketch, Fig. 684. E is the pipe which supplies the water to the crane, A the cylinder and piston for lifting the weight, and B a smaller cylinder for turning the crane round by means of the rack and wheel. The admission of the water to this last cylinder is regulated by the valve C, and to the large lifting cylinder by the valve D. The waste-pipes and cistern, safety-valves, and relief-valves, are not shown in the sketch. The piston of the lifting-cylinder is connected to a single pulley moving on a bed rail, part of which only is shown in the sketch. The chain passes over this pulley and two other fixed pulleys before passing up the hollow crane-post, so that the extent of motion of the piston in A is magnified three times in acting upon the chain. The weight may therefore be lifted through a higher space,

but of course with proportionately less force. A detailed description of this crane is given in Mr. Glynn's Rudimentary Treatise on Cranes.

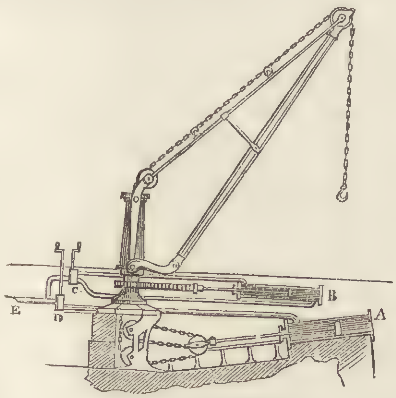


Fig. 684. WATER CRANE.

It has been proposed to apply the force of a vacuum, maintained constantly by a pumping steam-engine, as the motive power of cranes. Its application would of course nearly resemble that of the water, though it would be less manageable, and also far more limited in its power, as the pressure on the piston could never exceed that of the atmosphere, or about 15 lbs. per square inch.

Fig. 685, is a drawing of a double crane, which was employed in the construction of the pier and

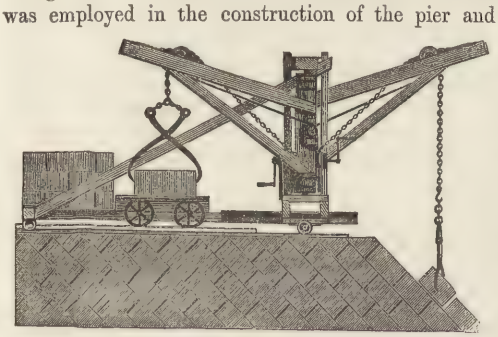


Fig. 685.

breakwater at Aberdeen. The whole framework of the crane travels on a temporary railway, so that it can be advanced to or drawn back from its work. By having two jibs, the work of unloading and placing the stones can be proceeded with very rapidly. The nippers used in holding the stones are peculiarly applicable to sub-aqueous works. The moment the stone rests on its own bed, the chain slackens, and the nippers release their hold. Were the stones suspended by a *lewis,* a diver must be constantly employed in deep water to release the stone when placed.

It has been suggested that steam may be used in the same manner as the water in Fig. 684, the lift of the crane being completed by one stroke of the steam-piston attached to the crane, and not, as usual in steam-cranes, by the temporarily-applied power of a small steam-engine.

A very efficient form of crane has been constructed by Mr. Neilson of Glasgow. The framing and wheel-work is the same as in the common wharf crane, but the motive-power is supplied by a small steam cylinder and piston attached to the framework, and acting upon the wheels by a connecting-rod and crank, as in the steam-engine. The steam-pipe passes up the crane-post, and is connected with the cylinder by a stuffing-box joint, which allows of the free rotation of the crane about its post. The boiler may be fixed in any adjoining warehouse or shed. A drawing of this crane will be found in the Practical Mechanics Journal, Part 36, March 1851.

CRANK. See STEAM-ENGINE.

CRAPE, a transparent fabric made of raw silk with the gloss removed, and died usually black. The weaving is very simple, and the dressing is finished with a stiffening of gum-water. See SILK.

CRAYON. See BLACKLEAD.

CREAM. See BUTTER.

CREOSOTE. See KREASOTE.

CRUCIBLES, open vessels for the reception of bodies which are to be subjected to high temperatures. The Alchemists made great use of these vessels, and were accustomed to impress the sign of the cross upon them; hence the name, from *crux, crucis,* a cross. Crucibles are of various forms and materials, according to the uses to which they are applied. They are mostly of earthernware, on account of the economy of this material, and its power of resisting a high temperature. The cheapest are the common *English crucibles,* made of a triangular or circular form, with covers of the same material. They bear a bright red heat; but at a very high temperature they soften and froth, and, under the action of a flux, fuse very readily. *Hessian crucibles* are very superior to the English in resisting high temperatures and the action of fluxes, nor do they become vesicular when powerfully heated. They are triangular in shape, and are not usually furnished with covers. *Cornish crucibles* are made in Cornwall of different sizes, and round in shape, for the use of the assay-masters there. They possess the good properties of the Hessian. *Wedgwood's crucibles* are made of a close white ware; they are round, well formed and finished, and their covers fit well. They are liable to crack by being heated or cooled. *Blue pots* or *black-lead crucibles* are made of a mixture of coarse plumbago and clay, and usually of large size. They bear a higher temperature than the English crucible, and are not so liable to crack. They also resist the action of fluxes at moderate temperatures. They contain a good deal of iron and charcoal. Melting-pots formed of Stourbridge clay and pulverized coke bear very high temperatures, and with care are not liable to crack in the fire. Crucibles are also formed of platina, pure silver and iron. The management of crucible operations, fusion and reduction, are described in Dr. Faraday's work on Chemical Manipulation, Section XIII.

CRYSTALLIZATION is that exertion of the force of cohesion among the particles of a solid, by which it is withdrawn from its solution in a liquid. In a great variety of cases the particles do not solidify into confused masses, as might be supposed, but

arrange themselves with the utmost order into certain geometrical forms called *crystals*. Thus if a portion of the water of a solution of sugar be driven off by slow evaporation, and the concentrated syrup be left for some time at rest, a regular solidification takes place; the force of cohesion builds up the solid into the symmetrical well-known forms of sugar-candy. But if the process be hastened or disturbed, we get loaf-sugar, in the formation of which crystallization commences at myriads of points at the same instant, and neither time nor space is allowed for the particles to expand to a large size and regular outline.

That very important and extensive class of bodies known as salts, crystallize from their solutions into forms of the utmost symmetry and beauty; and these forms, as also those of *native* minerals, or those met with in nature, are characteristic of particular salts or minerals; for each salt or mineral may be said to have as much a distinct shape of its own as each plant or animal, and may be as readily distinguished by the characters presented to the eye. Thus common salt assumes the form of the cube; alum, that of a octohedron; saltpetre, that of a six-sided prism; epsom salts, that of a four-sided prism.[1] The largeness and regularity of the forms of crystals is generally proportional to the slowness of the operation, and the quantity of the solution from which the crystals are deposited. Many of the crystals which have been formed by the hand of nature have hitherto resisted the efforts of science. Thus rock-crystal is found in beautiful six-sided prisms, the diamond in octohedrons, &c., but these were most probably produced by the operation of forces similar to those which can be watched and studied in our laboratories.

The operation of the force of cohesion, which binds the particles of crystals together, is determined by apparently very slight causes. Thus the agitation of a saline solution, or the contact of some foreign substance, or especially of a crystal of the same substance, will cause crystallization to commence. It will nearly always take place around any solid centre or nucleus that can be wetted by the liquid. In the manufacture of sugar-candy, verdigris, sulphate of copper, prussiate of potash, &c. strings, twigs of wood, and wires are placed in the solutions, and may generally be found in the centres of large groups of crystals. The use of the nucleus seems to be this:—A portion of the water of the solution attaches itself to the solid, which it wets, and is thus withdrawn from the solution, the crystallization of which is thus determined. An instructive example of this is seen in the common alum basket. A delicate frame-work of a basket or some other object is placed in a solution of alum or of sugar. After a time it becomes a basket of finished gems, the crystals glistening with their many polished facets. In the manufacture of tarraric and citric acids, the rough brown crystals of the first process are always much larger and bolder than those of the pure transparent products of the last operation. This arises from the presence in the first solutions of earthy or carbonaceous matter in a minutely divided state, which act as nuclei. If the nucleus be a salt of the same kind as the salt to be crystallized, it will act in a remarkable manner in a mixed solution of two salts, such as 2 parts nitre and 3 of glauber salt (sulphate of soda) dissolved in 5 of warm water. If two bottles be filled with the solution, and we put into one a crystal of nitre, and into the other a crystal of sulphate of soda, and place both in ice-cold water, nitre only will crystallize in the one, and sulphate of soda in the other. This property of one salt crystallizing in preference to another contained in the same solution, is of frequent use in purifying and separating crystalline substances. An ingenious process, introduced a few years ago for separating silver from lead, depends upon the property of the silver forming crystals in the fused lead before crystals of lead begin to appear. [See Lead.]

The effect of vibration in determining or modifying crystallization is exhibited in certain cases at temperatures far below those required for fusion or solution, which is most commonly necessary as a preliminary step to crystallization. When iron is subjected to long-continued vibration, especially under pressure, its tough fibrous character becomes changed into a coarse crystalline one; that is, certain of the fine crystalline grains become enlarged at the expense of others, and thus the cohesive force of the mass is diminished. Many accidents in machinery arise from this cause. It has also led to the fracture of the axles of railway and other carriages, and of grindstones, &c. Even the iron rails of a railroad may thus become weak and useless.

Very large and perfect crystals may be formed by repeatedly transferring a crystal from one saline solution to another of the same salt a little more concentrated, evaporating at very moderate temperatures, or even spontaneously at common temperatures. The most perfect crystals of gems are met with in nature of only moderate size. The larger ones are less clear, and even opaque, and the faces lose their smoothness, and much of their lustre. The emerald sufficiently pure for jewellery does not often exceed an inch in length, and is seldom so much as this. Clear garnets fit for setting are seldom half an inch through. Transparent sapphires above an inch in length are very rare. Quartz crystals sometimes attain a very large size. There is a quartz crystal at Milan which measures $3\frac{1}{4}$ feet in length, and $5\frac{1}{2}$ in circumference: its weight is 870 lbs.

The crystalline arrangement of an amorphous block may be developed in a pleasing manner by a contrivance first pointed out by Professor Daniell. If we take a large lump of alum, and remove from it all traces of external crystalline form by cutting and

(1) The freezing of water presents us with an apparently endless variety of forms, as in the ice which forms upon our window-panes by the cold on the outside condensing the moisture of our breath, &c. within; the hoar frost upon trees, shrubs, and grasses, and the wondrous variety of flakes of snow. All these figures are limited by certain laws, and the lines which bound them form among themselves no angles, but those of 30°, 60°, and 120°. If we let the end of a walking-stick fall upon the ice of a small pond or puddle after a night's frost, the fracture will generally present a star with six equidistant radii or angles of 60°.

grinding, and place this in a vessel of water, the fluid will at first act upon it in all directions alike; but as the water becomes saturated with the alum, the salt gives way only or chiefly along the lines of least resistance, which are determined by the regular structure of crystalline arrangement. Under these circumstances, the surface becomes embossed with the forms of octohedrons and sections of octohedrons. Other salts present analogous phenomena, and metals which have been slowly cooled from a state of fusion exhibit a similar regular arrangement of their particles when thus dissected by the action of acids. A mass of nickel thus treated, soon becomes covered with tetrahedral figures of great relief and beauty by the action of nitric acid; so also does gold carefully cast and cooled, by the action of aqua regia. The beautiful forms of the *Moirée métallique*, which formerly excited so much admiration in their application to ornamental purposes, were produced by the action of weak acids on common tin-plate, the different colours being given by means of transparent varnishes. The cheapness of the operation soon brought it into disrepute. By the action also of dilute muriatic acid, pure malleable bar iron may be dissected into bundles of fibres, running in a parallel and unbroken course throughout its length; while different varieties of cast-iron will by the same means present congeries of plates, and a structure more nearly approaching the crystalline. By the action of quicksilver upon a small bar of tin, the crystalline structure was beautifully shown: the bar was placed horizontally in the mercury, and frequently turned upon its different faces, so as to ensure uniformity of action; in about 24 hours, fissures appeared along its lateral and terminal edges, which, by gradually splitting, resolved the bar in four equal three-sided rectangular prisms, which, as well as two pyramids for their extremities, could be separated from each other by the point of a knife. A similar effect may be produced by careful hammering upon bars of malleable metals. If square bars be hammered upon the edges, and the blows repeated round them so as to give them a cylindrical shape, they soon become *rotten* and break into fibres: but when the blows are directed parallel to their faces, they are capable of great extension; but many of them by alternate hammering upon each face, ultimately split along the edges in a manner very similar to that which is produced by the action of the mercury on the bar of tin. When it is desired to give a round form to any part of a square bar, it is confined in a form or mould, and the mechanical force thus applied produces an equality of pressure. It is by a similar equalization of the pressure, that some metals admit of being drawn into fine wires through circular holes in steel plates.

Some crystalline solids slowly change their internal structure, as already noticed in the case of fibrous iron changing into crystalline. For example, sugar which has been rapidly boiled down to a solid consistence, as in *barley-sugar*, is transparent, is broken with difficulty, and has a glassy fracture. After a short time, it becomes opaque and almost friable. Brass wire, as already noticed [BRASS], becomes in the course of time brittle and unfit for mechanical applications. If crystals of sulphate of nickel or seleniate of zinc, in the form of prisms, be laid on paper and exposed to the sun, they become in a few moments opaque, and when broken up, are found to consist of minute octohedrons with square bases. Fresh sublimed iodide of mercury is of a sulphur yellow colour, but if scratched with a hard substance, such as the point of a pin, some readjustment of the cohesive force takes place, and the colour changes to a bright red. Some kinds of sandstone which have been used as the hearths of furnaces, from long exposure to a moderate heat acquire a crystalline texture. Many vitreous compounds, such as the slags of furnaces, form into globular masses of radiating and acicular crystals. Arsenious acid, recently fused or sublimed, is usually glassy and transparent, but it gradually becomes opaque, white, and crystalline, the change commencing at the surface, and proceeding slowly to the centre. [See ARSENIC.]

Light has a powerful action in influencing this cohesive attraction, and determining the crystallization of certain substances. Thus in the druggists' shops, the camphor contained in the glass jars in the window is arranged in beautiful crystals on the side of the jar nearest to the light. In a glass vessel containing a saline solution, capillary crystals shoot up and attach themselves only to that side of the vessel which is most strongly illuminated. By placing a screen before the vessel, the line between light and darkness will be found distinctly marked by the limit of crystallization. Solutions of metallic salts exhibit this result most effectually.

Such are a few facts connected with the important and beautiful science of Crystallography. The reader who desires to study this must consult treatises especially devoted to the subject. A knowledge of the determinate forms of crystals is very useful in enabling the mineralogist to distinguish one mineral from another, and the chemist to distinguish between the different classes of salts. The manufacturer also avails himself of crystallization to cleanse, purify, and prepare a number of substances useful in the arts, the purity of which is often judged of by their crystalline forms.

CUBE, a regular parallelopiped, whose ends are squares, and whose height is equal to the side of its end. A box of equal length, breadth, and depth is a cube. Being the simplest of all solids, the cube is taken as the measuring unit of solid content, as the square is that of superficial content or area. Whatever the unit of length may be, the unit of solidity is the cube, which is a unit every way, such as a cubic inch, a cubic foot, &c. A cubic or solid foot contains 1728 cubic inches; for as the area of the base contains 144 square inches, and as the cubic foot is 12 inches in height, it would allow 12 layers of cubical inches to be piled up to complete the figure, or 144 cubes $\times$ 12 $=$ 1728: hence, to find the solid content of a cube, we must multiply the area of its base by its height.

CUDBEAR. See ARCHIL.

CUPEL. See ASSAYING—BONE.

CURRYING. See LEATHER.

CUTLERY. The cutting instruments of rude nations are shells, flints, and sharp-edged stones. The stone *celts* found in the barrows of our island are the knives of the ancient Britons. The use of iron and steel was known at an early period; but brazen instruments being more easily fabricated, were more frequently in use. There is no record of the time when cutlery was introduced into Great Britain. It appears from the Custom-house books, that long before the time of Henry VIII. we had an import trade in knives. In the fifth year of Elizabeth, this import trade was restricted, with a view to encourage the home manufacture. At that time, London was the chief mart for the finer articles of cutlery, but Salisbury, Woodstock, Godalming, and Sheffield, also carried on a considerable trade. According to Stow, "Richard Matthews, on Fleet Bridge, was the first Englishman who attained the perfection of making fine knives and knive-hafts;" and he states that at the time of the prohibition above referred to, "and for many hundred years before, there were made in divers parts of this kingdom many coarse and uncomely knives." In 1417, the London cutlers obtained a charter of incorporation from Henry V., and their hall in Cloak Lane is still maintained. Long before this, Sheffield had become celebrated for its knives: thus, Chaucer speaking of the whittler of Trompington, says:—

"A Shefeld thwytel bare he in his hose;"

this instrument being a case-knife or whittle, used for cutting food, &c. The cutlers within *Hallamshire*, as the district about Sheffield is called, were not incorporated until 1624, but special rules for the government of the craft were formed at a much earlier period. The incorporation was founded on an act "for the good order and government of the makers of knives, sickles, shears, scissors, and other cutlery wares in Hallamshire and parts near adjoining." It is required by this act that, "all persons engaged in the said business to make the edge of all steel instruments, manufactured by them, of steel and steel only; and to strike on their wares such mark, and such only, as should be assigned to them by the officers of the company." These corporation marks are of great value as affording a guarantee of the superiority of the wares upon which they are stamped: they are protected by law, and it is illegal to forge or imitate them. Some of the most important houses still preserve their name and corporation mark, and refuse to put any other on their wares; but it is a very common practice for manufacturers to stamp on their goods the name of the retail dealer instead of their own: and in some cases, common iron knives are stamped with the words "shear steel," &c. Such dishonesty is very reprehensible, and tends to injure our character as a manufacturing nation.

Beckmann, in his "History of Inventions," has an amusing chapter on "Forks," which appear to be of comparatively recent use at table: they are still unknown in the East, where the meat is cooked so as to be exceedingly tender, and it is pulled to pieces with the fingers. Forks appear to have been first used at table by the Italians, towards the end of the fifteenth century.

The various causes which tend to concentrate a manufacture in a particular town or district, have long been in operation at Sheffield. The reputation of this town for the manufacture of knives and forks and various articles of cutlery is still maintained, and there is scarcely a more acceptable present on the continent than a Sheffield penknife or a pair of scissors. It is, however, greatly to be feared that the frequent disputes between masters and men on the subject of wages have injured the cutlery trade by causing doubt and uncertainty in the market. For example, various articles of cutlery are sold from patterns stitched on cards with the prices annexed; and as these prices are adjusted with great nicety to a scale of small profit on quick returns, it may happen that before a set of pattern cards with new prices attached can reach America, or have begun to circulate there, some alteration takes place at home, and other cards and corrections must be sent out, so that the foreign dealer throws discredit on the British manufacturer, who is often left to the mercy of workmen who cannot or will not see that their own interests are intimately bound up with those of the master manufacturer, who on his part has to provide capital, to stem the tide of competition, and to consult the interests of his customers at home and abroad.

The great variety of cutting instruments, and articles which come under the denomination of cutlery, are or ought to be manufactured wholly of steel, at least as far as the working parts of each instrument are concerned. Unfortunately, the great demand for cheap articles has led to the use of pig-iron in the production of knives, forks, razors, &c. An iron knife may have its uses, however inferior to steel, but an iron razor is of no use for the purpose to which razors are specially applied. At all good houses, either common steel or shear or cast-steel is used. Shear steel is very plastic and tough, and is used principally for edge tools which require great tenacity without much hardness, as in table knives, scythes, plane-irons, &c. Articles requiring a very fine polish, as razors, scissors, penknives, &c., ought to be of cast-steel; but as cast-steel can be welded to iron with great ease, the cutting part of chisels, plane-irons, &c. is made of the superior, and the rest of the tool of the inferior metal.

The forging of small works, such as articles of cutlery, differs in many respects from the forging of large works, which will be noticed under the article FORGING. In forging small works, two men are usually required, and the work is then said to be *two-handed*. The principal man, named the *fireman*, manages the work both in the fire and on the anvil; he is furnished with a small hammer of from 2 to 4 lbs. weight, with which he directs his mate, who is

named the *hammer-man*, from the circumstance of his having to wield a sledge-hammer of from 10 to 14 lbs. weight or more: it is his duty also to blow the bellows. The hearth is raised about $2\frac{1}{2}$ feet from the ground: it is built hollow with an arch beneath for the ash-pit. A single hearth is about a yard square, and a hearth which has two fires under the same hood is about 2 yards by 1 yard. The hearth is furnished with a double trough for containing water in one compartment and coals in the other. The ordinary double bellows is used. The anvil weighs from 2 to 4 cwt., and is raised about $2\frac{1}{2}$ feet from the ground.

Small works are usually forged at once from the end of a bar which is called the *porter:* after it has been cut off to be finished, or when the bar is too short to be held by the hand, tongs are used, of which there are various forms. Fig. 686, represents a pair of *flat-bit* tongs: they fit closer for thin works;

Fig. 686.

they are always parallel, and a ring or coupler is put on the handles or *reins,* as they are called, to maintain the grip of the work. Others are made with hollow half round bits, to retain firmly round or square bars; or they are swelled open behind in order to hold bolts and other objects. Fig. 687, is a common form of tongs used by the Sheffield cutlers: they are called *crook-bit* tongs: the jaws overhang the side so as to

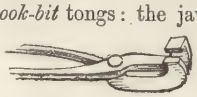


Fig. 687.

Fig. 688.

allow the bar of iron or steel to pass down beside the rivet, and the nib at the end prevents the rod from being displaced by the jar occasioned by hammering. Fig. 688, represents the common smith's pliers or light tongs for picking up small work, or for holding small tools while they are being hardened.

The cutler is also furnished with a variety of chisels, punches, and swages, or *striking* tools, called also *top and bottom* tools, of various forms, and generally in pairs. The bottom tools are usually furnished with square tangs for fitting into the square hole in the anvil; and in using them, the fireman holds the work upon the bottom tool, and above the work he places the top or rod tool, which is then struck by the sledge of the hammer-man. This causes the hot part of the work, which is between the top and bottom pieces of the swage, to rise up and fill the mould formed by them. The top tools are not held by a rigid iron handle, for this would jar the hand, but by hazel rods, prepared for the purpose by being alternately wetted and warmed over a fire in the middle of their length, in order to soften them: that portion is then twisted like a rope, and the rod is wound once round the head of the tool, and retained by an iron ferrule or coupler. See Fig. 691.

In the ordinary practice of forging, three processes or modes are adopted:—1, by *drawing down* or *reduction;* 2, by *jumping* or *up-setting;* also *thickening* and *shortening;* 3, by *building up* or *welding.* In nearly every case of forging, the first two methods are used, and in many cases all these methods are combined. To reduce the thickness of a bar both in length and in width, the flat face of the hammer is made to fall level on the work; but where the length or the breadth alone is to be extended, the *pane* or narrow edge of the hammer is first used, its blows being directed at right angles to the direction in which the iron is to be spread. When the sides of the object are required to be parallel, and the object is to be reduced in width and thickness, the flat face of the hammer is made to fall parallel with the anvil, as in Fig. 689, or oblique for producing taper pieces, as in Fig. 690; and as action and reaction are equal, the lower face of the work receives the same absolute blow from the anvil as that applied above by the hammer itself.

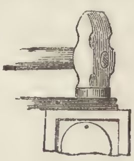


Fig. 689.

Hence it is not necessary in works of moderate size to present each of the four sides to the hammer, but only two, at right angles to each other. In thus reducing work, much practice in the use of the hammer is required in order to retain the rectangular section. "In converting a round bar into a square with the hammer, the accuracy will depend almost entirely upon the change of exactly 90 degrees being given to the work, and this the experienced smith will accomplish with that same degree of feeling or intuition which teaches the exact distances required upon the finger-board of a violin, which is defined by habit alone. . . . First, he must acquire the habit of *feeling* when the bar lies perfectly flat upon the anvil, by holding it slenderly, leaving it almost to rotate in his grasp, or, in fact, to place *itself.* Next, he must cause the hammer to fall flat upon the work; with which view he will neither grasp its handle close against the head of the hammer, nor at the extreme end of the handle, but at that intermediate point where he finds it comfortably to rebound from the anvil, with the least effort of, or jar to, his wrist. And the height of the wrist must also be such as not to allow either the front or back edge of the hammer-face to strike the work first, which would indent it; but it must fall fair and parallel, and without bruising the work. . . . The flat face of the hammer should not only fall flat, but also centrally upon the work; that is, the centre of the hammer, in which point the principal force of the blow is concentrated, should fall on the centre of the bar, otherwise that edge of the work to which the hammer might lean would be the more reduced, and consequently the parallelism of the work would be lost. It would also be bent in respect to length, as the thinned edge would be more elongated, and thence convex; and when the blows were irregularly scattered, the work would become twisted or put in winding, which would be a still worse error."[1] Suppose it were required to *draw down, i.e.* reduce six inches of the end of a square or rectangular bar of iron or steel: the smith places the bar across the anvil, with about

(1) Holtzapffel: Mechanical Manipulation.

four inches overhanging, and not resting quite flat, but tilted up about a quarter or half an inch at the near side of the anvil, as in Fig. 690, but less in degree, and the hammer will be made to fall as there shown, only at a very small angle with the anvil. Having given one blow, he twists the work a quarter turn, and strikes it again: he then draws the bar half an inch or an inch towards him, and gives it two more similar blows, and so on until he arrives at the extreme end, when he begins again. The descent of the hammer, the *drawing* the work towards himself, (which Mr. Holtzapffel suggests may be the origin of the term,) and the quarter turn backwards and forwards, all go on simultaneously and with some expedition. At other times the work is drawn down over the beak-iron, and then it is of less consequence at what angle the work is held or the blows given. In smoothing off the work, the position of Fig. 689 is assumed; the work is laid flat upon the anvil, and the hammer made to fall horizontal.

Fig. 690.

The ordinary hand-hammer is shown in Figs. 689, 690, but the Sheffield cutlers and most tool-makers prefer a hammer without a pane, and with a handle quite at the top, the two forming almost a right angle, or from that to about 80°; in some cases [see FILE] the head is bent like a portion of a circle.

In drawing down the tang or taper point of a tool, the extreme end of the iron or steel is placed a little beyond the edge of the anvil, as in Fig. 690, to prevent the anvil from being indented, and the small irregular piece in excess beyond the taper is not cut off until the tang is completed. Fig. 691 shows the position of the chisel in cutting off the finished object from the bar of which it formed a part: the work is placed between the edge of the anvil and that of the chisel, the two edges acting as a pair of shears. A *set-off* is made by placing the intended shoulder at the edge of the anvil: the blows of the hammer are effective only where they are opposed to the anvil, the remainder of the bar retaining its full size, and sinking down, as in Fig. 692.

Fig. 691

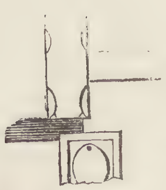


Fig. 692.

The subject of forging is a very extensive one, and the reader who desires to study it fully ought to consult Mr. Holtzapffel's work. Some further illustrations will be given under FORGING and WELDING; our present object being to state enough to make intelligible the following particulars respecting cutlery.

In the forging of a table-knife, the blade is first produced at the end of a bar of shear steal, and then cut off: it is next welded to the extremity of a rod of iron about half an inch square, and a portion of this is cut off sufficient to form the bolster or shoulder together with the tang. The proper size and shape of the bolster are formed by means of a couple of swage tools. The blade is then heated a second time, and properly finished on the anvil: this is called *smithing* the blade. The maker's mark is stamped upon it, and it is then hardened, by being raised to a red heat and plunged perpendicularly into cold water. It is tempered to a blue colour, and then sent to the grinder.

In the manufacture of steel goods the processes of hardening and tempering perform an important part. Steel possesses the useful property of becoming hard when suddenly cooled from a red heat by being plunged into cold water or oil. By this process, however, it is not only made hard, but brittle; and it is to remove this brittleness that the process of tempering is adopted, which consists in heating the hardened steel articles to a moderate degree. But in proportion as the heat is increased, the hardness diminishes, and when it is reduced to the proper degree of hardness required by the instrument, it is again suddenly cooled by plunging it into cold water. The proper degree of hardness is ascertained by the colour of the film of oxide which forms when steel is slowly heated in the air to a temperature of not less than 430° Fahr. Where elasticity is required, as in springs for watches, gun-locks, &c., the steel is cooled as soon as it has assumed a fine blue. When a keen edge is required, as in razors, the edge is brought to a fine straw colour, while the back is blue. The following table, by Mr. Stodart, shows the colour of the films, the temperatures at which they are produced, and the instruments to which the different kinds of temper are applicable:—

1. Very pale straw yellow...	430°	The temper required for lancets.
2. A shade of darker yellow	450	A little softer, for razors and surgical instruments.
3. Darker straw yellow......	470	Penknives.
4. Still darker straw yellow	490	Chisels and shears for cutting iron.
5. A brown yellow............	500	Axes and plane-irons.
6. A yellow, tinged slightly with purple	520	Table knives and cloth shears.
7. Light purple	530	Swords and watch-springs.
8. Dark purple	550	
9. Dark blue	570	Small fine saws.
10. Paler blue	590	Large saws, the teeth of which require to be set with pliers, and sharpened with a file.
11. Still paler blue	610	
12. The same, with a tinge of green..................	630	Too soft a temper for steel instruments.

Sir Humphry Davy proved that the presence of oxygen is necessary to the production of these colours, by heating bright polished steel in a glass vessel full of nitrogen; in which case coloured films were not produced. According to Nobili, these coloured films are not oxides, but a combination of carbon with oxygen, which, becoming fixed in some way upon the steel, in the form of a thin plate or film, has the effect of preserving the metal from rust. Nobili argues that if this tint were the effect of oxidation, it would not prevent but accelerate oxidation. In order to show the preservative effect of this film, two steel plates of the same quality and polish were selected, one of which was coloured by the usual process. and

both were exposed for a month in the open air during a rainy autumn. At the end of this time, the uncoloured plate was covered with rust: the other plate had lost a little of its colour, but was free from rust.

The various forms and sizes of knife, such as the shoemaker's knife, the bread-knife, &c., are forged in the same manner as the table-knife. The penknife blade, which ought to be of the best cast steel, is forged from the end of a steel rod, with a light hammer, upon a small anvil; and as much is cut off as is necessary to form the joint. The blade is then held in a pair of tongs, and heated a second time; the joint part is next finished, and a temporary tang drawn out for driving into a small haft or handle for the grinder, as shown in Fig. 693. The nick or notch called the *nail-hole* is stamped by means of a chisel, while the blade is hot. The blade is hardened by raising it to a red heat, and dipping it in water up to the shoulder. The tempering is performed on a number of blades at a time, arranged side by side, with the back downwards, upon a flat iron plate, placed over the fire, and left until the proper colour has been attained.

Fig. 693.

Forks are sometimes made of cast metal, but the better kinds are forged from a rod of steel about $\frac{3}{8}$ inch square: the tang, shoulder, and shank are first roughly formed, and then cut off, leaving at one end about an inch of the square part of the steel, which is afterwards drawn out flat to about the length of the prongs. This *mood* or *mould*, Fig. 694, is heated until it becomes soft, and placed in this state in a steel boss, or die, upon which a second boss attached to the lower surface of a heavy block of metal is made to fall from the height of several feet:[1] in this way are formed the prongs and central part, or *bosom* of the fork; the thin film of steel which is left between the prongs is cleaned out with a file. The fork is then ground and finished, and is ready for hafting.

Fig. 694.

Razor blades ought to be forged out of bars of the very best highly carbonated cast steel, tilted to about $\frac{1}{2}$ an inch in breadth, and of a thickness sufficient for the back of the razor. The blade is first moulded at the end of the porter rod, and then forged, and the edge being brought out, the concave surface is formed by working the side on the rounded edge of the anvil; it is then cut off, and the tang is either drawn out from the same material as the blade, or, if this be of superior quality, a piece of iron is welded to it. The steel ought to be of excellent quality to undergo the beating necessary to produce the thinner part, while the back is left thick. Some workmen are so expert in forging the blade, that they will produce on the anvil an edge so sharp and even, that it can be used for shaving after being whetted. After forging, the blade is *smithed*, or beaten on an anvil, to make the metal as compact as possible; a process adopted with all the better kinds of cutting instruments. The blade is also slightly ground or *scorched*, after the forging, on a dry coarse grit-stone, in order to bring it to the shape required, and also to remove the black scale or coating which prevents the uniform action of water and heat in the processes of HARDENING AND TEMPERING. The blade is next drilled for the joint, and stamped with the name; it is then hardened and tempered; then ground on a wet stone of from 4 to 8 inches in diameter; the shoulders of the blade are in some cases ground on a fine, dry stone, for which purpose the edge of the stone is rubbed with bee's-wax, to prevent the stone from crumbling away: the blade is next lapped on a lead lap, which gives the true curve to the surfaces: the tang and back are glazed on a leather glazer; the blade is next polished on a soft buff wheel covered with dry crocus, revolving slowly, and, lastly, it is handled and set. This completes the processes concerned in the manufacture of a razor blade; the best penknife blades and scissors are treated in a similar manner; but some of these processes require a more detailed notice, and we will return to them after noticing the forging of one or two other articles.

There is, perhaps, no article in cutlery that varies so much in price and quality as scissors; for while some are sold at the low rate of $3\frac{1}{2}d.$ per dozen pair, others produce ten guineas and upwards the single pair, and between these extremes the prices vary according to the value of the metal, and the amount of labour bestowed upon the handles. The best scissors are made of cast steel, and are hardened in the blades, shanks, and bows. Shear-steel scissors, which are in most common use, have the blades only hardened. A third variety, called *shot* scissors, have steel blades, but the bows and shank are of iron. Large scissors, such as tailors' shears, are of this kind. It was formerly the practice, in order to economize the more costly material, steel, to make all large shears entirely of iron, with the exception of a slip of steel welded along the edge of the blade. The best description of iron scissors are falsely named *run* or *virgin steel;* they are formed of good cast-iron, while the cheapest description of scissors are made of common cast-iron in very large quantities for South America and the Indies. The most costly scissors have their shanks and bows of gold, silver, &c.

The varieties of scissors are very numerous, such as *button-hole scissors, cutting-out, drapers', flower, garden,* and *grape scissors, horse trimming scissors; hair, lace, lamp, nail, paper, pocket, stationers'*, and *tailors' scissors,* and many others. The following general description refers to a pair of common steel scissors of good quality.

In forging steel scissors a single blade is formed at the end of a small bar of flat steel, and is then cut off together with enough of the metal to form the shank and bow. A hole is then punched through the projecting lump of metal sufficient to admit the point of a small anvil, or *beck-iron*, upon which the bow is worked out with the hammer. The beck-iron is furnished with a shallow groove, for rounding the

(1) The arrangement of the stamping press is shown in Fig. 393, p. 264, *ante*.

inside of the bows. The smallest kinds of scissors are in this way made with surprising dexterity and despatch, the result of long practice. After being *lighted*, or softened in the fire, the shank and bow are improved in shape by filing, the joint is squared, and the hole is bored and fitted for the rivet. The blades are next ground; after which the bows and ornamental work are smooth-filed and burnished with fine emery and oil. The blades are forged chiefly by eye, without reference to their being in pairs: the separate blades are, therefore, next sorted into pairs, screwed together, and made to "walk and talk" well, as the "putter-together" calls the smooth motion of the blades. The screw which unites the two blades consists of three parts differing in diameter; viz. the *head*, the *neck*, and the *thread;* the bottom of the countersink that receives the head of the screw is called the shelf or the *twitter bit*. Each pair is then bound round with fine iron wire, the rivet is taken out, and the blades and shanks are hardened. When the wire is removed, the blades are ground into proper shape, again fastened together, and made to work properly. The bows and other parts are rubbed up with fine emery and oil, and the scissors are taken a third time to the grinder; the shanks are ground, and the whole instrument glazed and polished. When put together again, the edges of the blades are whetted, and the scissors are lastly handed to women who fine burnish the parts requiring it, with polished steel tools. Well-made scissors sometimes appear to grate a little when closed: this arises from the presence of dirt or dust, for if the finger be passed along the edges so as to remove it, the smooth and pleasant action of the scissors will be restored.

The blades of scissors must be in close contact at the time of cutting, otherwise the substance to be cut will fold down between them, especially if it be very thin. When the blades exactly meet, one serves to support the material, while the other severs it, or rather each blade supports the material for the other to cut. The blades are not made quite flat on their faces, or with truly plane surfaces, (as in Fig. 695, which is an

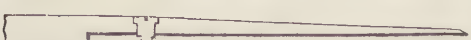


Fig. 695.

imaginary longitudinal section of the instrument,) because, in such case, the friction would be greatly increased by the rubbing of the surfaces. "The form really adopted more resembles the exaggerated diagram, Fig. 696; the blades are each sloped 2° or 3°

Fig. 696

from the plane in which they move, so that their edges alone come into contact; instead of the blades being straight in their length they are a little curved so as to overlap; and close behind the screw pin by which they are united, there is a little triangular elevation, insignificant in size, but most important in effect, which may be considered as a miniature hillock or ridge sloping away to the general surface near the hole for the screw. This enlargement, or bulge, is technically called the *riding part*, and as there is one on each blade, when the scissors are opened so that the blades are at right angles, the points or extremities only of the riding parts come into contact, and the joints may then have lateral shake without any prejudice. But as the blades are closed, first the bases or point of the riding parts, and lastly the summits or tops, rub against each other, and tilt the blades beyond the central line of the instrument; the effect of which is to keep the successive portions of the two edges in contact throughout the length of the cut, as by the time the scissors are closed, the points of the blades are each sprung back to the central line of the scissors, which is dotted in Fig. 696. Although scissors when in perfect condition for work may be loose or shake in the joint, (and thereby placed beyond their range of action,) they will be always found to be tight and free from shake as soon as the blades can begin to cut the material near the joint, and so to continue tight until they meet at the points. That all scissors do exhibit this construction may be easily seen, as when they are closed and held edgeways, between the eye and the light, they will be found only to touch at the points and at the riding parts, or those just behind the joint screw, the remainder being more or less open and gently curved; and their elastic action will also be experienced by the touch, as whilst good scissors are being closed there is a smoothness of contact which seems to give evidence of some measure of elasticity."[1]

Fig. 697 shows the section of one blade of a pair of scissors registered in 1841 by Mr. G. Wilkinson of

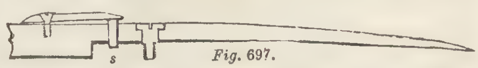


Fig. 697.

Sheffield. Here the elastic principle is introduced differently. Instead of the riding part, one blade is perforated immediately behind the screw for admitting freely a small pin or stud, *s*, fixed to the end of a short and powerful spring, so that the stud, *s*, acting on the opposite blade, throws the points of both blades towards each other, so as to give them a tendency to cross, but this being resisted by the edges of the blades touching each other, they are kept in contact throughout their motion, and produce their cutting effect well and agreeably.

The grinding and polishing of cutlery form an important part of the operations carried on at Sheffield. They are usually conducted in buildings called *wheels* or *mills*, each of which is divided into separate rooms called *hulls*, and in each hull are six *troughs* with a grindstone and a polisher in each. Motion is communicated to the stones by means of a steam-engine. The most celebrated of these grinderies is the Castle Mill, situated near the junction of the Sheaf and the Don. A view of it is given in one of our large engravings. Its castellated appearance has given it a name, and it comprises a central court-yard, with buildings running along the four sides, containing numerous apartments occupied by the grinders, who contribute each a certain sum for rent

(1) Holtzapffel.

CUTLERY.—EXTERIOR VIEW OF THE CASTLE GRINDING-MILL AT SHEFFIELD.

and for steam power. The stones vary in quality and size with the article to be ground. They range from 6 to 24 inches in diameter, and are fixed upon square iron spindles from 12 to 30 inches long, terminating in steel-pointed centres: the stone is wedged fast near the right hand extremity of the spindle, and near the left is fixed the pulley for the driving belt. The spindle is supported on two long pieces or sleepers united at their extremities and resting on the ground; near one end are two upright posts, at the upper parts of which are hollow centres for the spindle to run in: the centres are of lignum vitæ, horn, or steel. The Sheffield grinders commonly use ash for the centre blocks. Between the standards and below the stone is a long narrow water trough of wood lined with lead or iron, called the *dog-pan:* it is not allowed to contain water enough to reach the stone, or it would be splashed about by the centrifugal force; but the water is thrown upon the stone from a bucket with the hand, or is allowed to flow in a thin jet upon the side of the stone. The man sits astride a board called the *horse,* which admits of being shifted to or from the stone. The edge of the horse near the stone is commonly shod with iron, for supporting the tool used in "turning-up" the stone. A splash-board, or some other contrivance, is erected on the other end of the trough, projecting above the top of the stone so as to catch most of the water that flies off and return it to the trough. [See GRINDSTONE.]

Saws, fenders, &c., which present a large extent of surface, require stones of great diameter; while razors and the smaller articles of cutlery are ground upon small stones. Saws, scythes, and edge tools which require a certain temper, are ground on a wet stone, for which purpose water is kept in the trough to such a height as just to touch the stone. An extensive class of small articles, such as razors, scissors, pen and pocket-knives, forks, needles, &c. are ground upon a dry stone. Dry grinding is a more expeditious operation than the wet, but several articles of cutlery are first ground on a dry stone, and afterwards on a wet one. Fork grinding, however, is always performed on a dry stone, and hence the peculiarly destructive character of this branch. Dr. Holland, a physician of Sheffield, declares the fork grinder's employment to be probably more destructive to human life than any other pursuit in the United Kingdom. "In the room in which it is carried on there are generally from eight to ten individuals at work, and the dust which is created, composed of the fine particles of stone and metal, rises in clouds, and pervades the atmosphere to which they are confined. The dust which is thus every moment inhaled, gradually undermines the vigour of the constitution, and produces permanent disease of the lungs, accompanied by difficulty of breathing, cough, and a wasting of the animal frame, often at the early age of twenty-five. Such is the destructive tendency of the occupation, that grinders in other departments frequently refuse to work in the same room, and many sick clubs have an especial rule against the admission of dry grinders generally, as they would draw largely on the funds, from permanent and long continued sickness." [1]

It is shown from the statistics of the trade, that the average age of fork grinders does not exceed thirty years, and Dr. Holland shows that while in the United Kingdom 296 persons out of 1,000 die annually between the ages of twenty and forty, 885 fork grinders perish out of the 1,000!

A complete remedy for the evil consists in the thorough ventilation of the fork grinder's apartment by means of a ventilating shaft containing a revolving fan. A wooden funnel from ten to twelve inches square is placed a little above the surface of the revolving stone, on the side the furthest from the grinder, which funnel terminates in a channel immediately under the surface of the floor. The channel varies in length according to the situation of the grinder in reference to the point where it is most convenient to get rid of the dust. If eight or ten grinders work in the same room, each has his own funnel and channel, and these all terminate in one large common channel situated close to the wall of the apartment. Within this general channel is placed a fan similar to that used in winnowing corn, and to this is attached a strap which passes upwards and over a pulley, so that whatever puts the pulley in motion, causes the fan also to revolve. The pulley is placed in connexion with the machinery which turns the stone, so that whenever the grinder adjusts his machinery to work, he necessarily sets the pulley and the fan in motion. The fan acting at this point, whatever may be the length of any of the subordinate channels, causes a strong current to flow from the mouth of each funnel, which carries along with it all the gritty and metallic particles evolved, leaving the room in which the operations are pursued, free from any perceptible dust. When the whole apparatus is perfect and in excellent condition, the atmosphere of the place is almost as healthy as that of a drawing-room.

Dr. Holland mentions that in one manufactory, the dust is conveyed by the general channel into a trough of water outside the building. The quantity which accumulates in it in a few weeks is very great; and in raising it in a mass, it seems to have almost the specific gravity of metal. The first cost of the apparatus would scarcely exceed the proportion of a sovereign for each grinder; the funnel may be had for a few shillings, and the fan and pulley for a mere trifle. "Were the legislature to interfere, and make it imperative on the part of the proprietors of wheels, to construct such an apparatus, and compel them to keep it in a perfect condition, an immense amount of disease, suffering, and wretchedness would be prevented; and the future inquirer into the condition of grinders would not have to record the numerous premature deaths." In places where the

(1) "The Vital Statistics of Sheffield," by G. Calvert Holland, Esq., M.D. London, 1843.

"Diseases of the Lungs from Mechanical Causes," by the same. 1843.

apparatus had been in operation for years, Dr. Holland did not find a single individual labouring under any pulmonary affection; and in other instances where the lungs had become affected with disease, the erection even of an imperfect apparatus by the artisans themselves, arrested the disease, and afforded substantial relief. [See NEEDLE.]

In grinding articles of cutlery, the size of the stone is of importance. If ground upon a large stone, revolving with great rapidity, the grinding will be performed more expeditiously than on a smaller stone moving at the same rate; but the steel is often thereby, by overheating, deprived of some of its excellent qualities, which no subsequent operation can restore. The concavity on the surface of a blade also depends upon the size of the stone: thus a stone four inches in diameter, must give to the blade a corresponding concavity, or a curve of two inches radius; and such a curve will evidently yield a keener edge than can be produced from a six, eight, or twelve inch stone, because the smaller the diameter the more convex is the stone, and the more concave will be the blade which is ground upon it. Mr. Ebenezer Rhodes, of Sheffield, a practical cutler, in his "Essay on the Manufacture of a Razor," enumerates the qualities of a good razor to consist in a proper form, weight, and justness of proportion, with proper hardness, regularity, and fitness of concavity. The stones used in producing this concavity of surface vary from four to twelve inches in diameter, according to the price of the article required. A four-inch stone is most generally used; but Mr. Rhodes recommends a stone of from six to eight inches in diameter, which produces razors "sufficiently hollowed or ground out for any service, however hard, to which they may be applied; and they combine a desirable strength and firmness of edge, with a requisite degree of thinness. The concavity of a razor should likewise possess great evenness and regularity, otherwise a very unequal edge is produced; a defect which every application to the hone will rather increase than diminish, and which nothing but re-grinding in a more perfect manner can possibly remove."

Figs. 698 to 703 will show some of the forms which have been given to razors. The proportion between the width of the blade and the thickness of the back is such that when the blade is laid perfectly flat on the hone, so that the edge and back both touch it, the proper angle is obtained, which varies from about 17° to 20°. In the enlarged figures the angle of 18° is preserved throughout, as shown by the dotted line, and the concavity of each side of the razor is shown within the angle thus formed. The chief use of this hollowing out of the sides is to avoid the necessity of sharpening the entire side of the wedge formed by the dotted lines. It would evidently be much more tedious and difficult to wear down the flat sides represented by the dotted lines than the small portion of the same which is left; and even if it were attempted, the edge would probably be rounded instead of flat. The concavity, therefore, assists in placing the razor on the hone, it makes the edge thinner, leaving but little for the stone to wear away, and it prevents the polished and finished surface from being injured during the sharpenings.

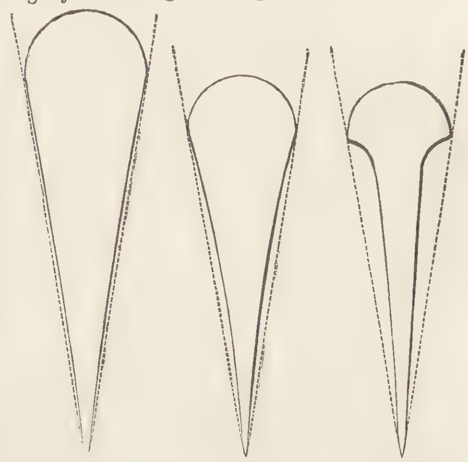


Fig. 698. *Fig.* 699. *Fig.* 700.

The most common forms of razor are shown in the sections, Figs. 698, 699; the one having been formed by grinding transversely on a wheel of 4 inches diameter, and the other on one of 12 inches, the general extremes of curvature. Fig. 700 is produced by grinding the blade lengthways on the stone, so as to become nicked in, and thus produce any degree of thinness required. When used on a strong beard a considerable vibration is produced, which has led the Sheffield cutlers to apply the term *rattler* to these

Fig. 701. *Fig.* 702. *Fig.* 703.

razors. In Fig. 701 the two modes are combined, the razor having been first ground transversely, as for Fig. 699, and then lengthways, so as to be nicked in for about half its width: these are called *half-rattlers*. In another form, Fig. 702, a very thin, acute blade has been fixed in a detached back, something like a dove-tail saw. Fig. 703 is a guarded razor, a loose frame or guard of brass being added to the blade; it is intended to prevent the edge from penetrating to any serious depth when the razor is used by nervous or infirm persons. The setting of razors will be noticed under HONE: our present business being with their manufacture.

The grinders have various contrivances for protecting their hands from the heat excited by the friction. Table knives are for this purpose fitted in a wooden case, as shown in Fig. 704.

Fig. 704.

After the articles of cutlery have been ground, they are *lapped, glazed,* and *polished* on metal or other wheels, called *laps.* The cutler's narrow, cylindrical lap consists usually of a wooden centre, made in 4 or more pieces, the grain of the wood pointing to the axis in order to preserve the circular form, and united by circular disks of wood or metal; the edge is then turned to the required width, with a groove in the centre, and a chamfer on each edge for holding the metal rim; this is usually 1 part tin, and 4 or 5 of lead, (the lining of old tea-chests being preferred,) and is attached to the centre by casting; the edge or *face* is then turned true, after which it is dressed with emery and oil, a number of fine grooves being made on the face in order to retain the dressing or *head,* as it is called. It is brought to a uniform surface by drawing the work, such as a razor blade, from end to end steadily across the revolving lap. When a dozen blades have been prepared in this way, the process is repeated with fine emery, or the lap is *fined* by rubbing the head with a piece of felt, then with a smooth piece of flint, or with a steel blade. In finishing the blades a stick of charcoal is also used to deaden the emery before the flint is applied. In lapping penknives and small articles, the wheel is charged by rubbing on it a lump of emery cake. A white colour is produced on steel with a coarse lap and heavy pressure of the work upon it; but with a fine lap and light pressure, gradually drawing the work from one end to the other, a black polish is produced.

Wood wheels, called *glazers,* are also used; they are arranged in 6 or 8 pieces, so that the edge or face may be entirely formed of the end grain of the wood. Mahogany is preferred, but walnut, oak, crab-tree, and birch, are used. These wheels are mostly fed with emery cake.

Polishing wheels with wooden centres covered with leather are also used. For polishing razors and fine cutlery the leather is charged with crocus, and the wheel is always used dry. Both the polisher and the blade must be moderately heated, or a good polish cannot be produced; the heat is usually supplied by the friction of the surfaces. The polisher is made to revolve much more slowly than other wheels, and the blade is moved to and fro from end to end very quickly and with considerable pressure, by which means the heat is equally distributed: the blade is not drawn slowly across, and off, as in lapping, but is moved end-long, and is pulled off quickly. The man's fingers are protected from the heat of the blade by a thick piece of cloth or felt, which is also used to supply the polisher with crocus by dabbing it upon the dry powder, and then rubbing it upon the polisher.

The handles and hafts of the various articles of cutlery are furnished by the cutler. The materials for handles are very numerous, but that which is most used is elephant and walrus ivory. Other substances in request are German and Indian stag-horn, buffalo and cow-horn, tortoiseshell, mother-of-pearl, coco-wood, snake-wood, &c. Stamped gold and silver are also used. Articles in such common use as knives and forks are best handled by nailing flat pieces of bone, ivory, or wood, upon a flat piece of iron continued from the blade. A very good method is what is called *through-fang,* that is, to drill a hole completely through the handle, and to insert a cylindrical or four-sided prong projecting from the blade, riveting it at the opposite end. A common method is to pass the small prong projecting from the blade about half-way into the handle, and to secure it with melted resin mixed with fine ashes or with whiting, in order to improve the colour. Such a handle, however, readily becomes loose when put into hot water. Balance handles are made by perforating the haft deeper than usual, and then dropping in a small piece of lead; the handle is thus heavier than the blade, which, being furnished with a projecting shoulder, is prevented from touching the table-cloth when laid down. Messrs. Joseph Rodgers & Co. (at whose establishment at Sheffield the Editor has witnessed many of the processes described in this article) have lately registered a method of fixing a knife-blade in the handle, which renders its removal, or its becoming loose by ordinary wear, impossible. It is secured entirely by mechanical means, without any kind of cement, as shown in Fig. 705, in which it will be seen that in addition to the hole for the reception of the tang, a slight recess is cut out on one side, into which the end of a small spring, riveted or otherwise fastened to the tang, falls, and thus secures the two portions firmly together. When the spring is fastened to the tang, the end of the latter is simply inserted into its hole, and the moment the detaining end of the spring clears the notched edge of its recess, it falls in, and acting like a ratchet detent, no force, short of that of fracture of the parts, can separate them. The consumption of ivory for hafting table knives and forks is very large. The teeth are cut up by means of a circular saw, a very strong ammoniacal odour being developed by the friction. The methods of preparing Horn and Tortoiseshell will be noticed under those heads.

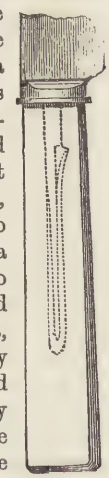


Fig. 705.

There is probably no article of cutlery in which the processes are more numerous than in a penknife, one with three blades having to pass through the finisher's hands about 100 times. When the blades, spring, and *scales,* as the iron plates at the side are called, are severally bored with appropriate holes, they are all pinned together, loosely at first, till all the parts fit and work properly together; they are then riveted with bits of wire with a hammer on a small anvil. The sides of horn, ivory, or shell, are filed and scraped, and then polished twice on the buff. The backs of the springs are glazed.

For letting in a *shield*, *escutcheon*, or plate of silver on one side of the handle, a cavity is cut out by means of pattern plates, or *templets* of hardened steel, pierced with the exterior form of the shield. The cutting tool, Fig. 706, is like the ordinary breast-drill, Fig. 707, 8 or 10 inches long, and like it, is used with the breast-plate, Fig. 709, and drill-bow, Fig. 708; but the extremity of the tool is cleft, or made in two branches, which left to themselves spring open to the extent of an inch or more. Each half of the tool has a shoulder or stop, which bears upon the surface of the guard-plate, and a rectangular cutting part which protrudes through the shield-plate as far as the required depth of the recess, and is sharpened both at the ends and at the sides, or at the ends only. [See DRILLING.] When this elastic tool, or *spring-passer*, has been compressed so as to enter the guard-plate, it is put in motion, and flounders about in all directions as far as it can expand, and thus routs or cuts out the shallow recess. The shields having been punched out, are fixed in by a couple of rivets, and smoothed off.

Fig. 706.

Fig. 707.

Fig. 708.

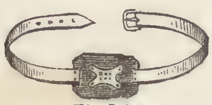


Fig. 709.

Handles of ivory, shell, &c. are sometimes dotted all over with little studs of gold and silver; the holes for these are first drilled from thin pattern plates of brass or steel, in which the series of holes have been carefully made. The drill or passer, Fig. 707, has an enlargement or stop, which by coming in contact with the surface of the pattern plate, prevents the point of the drill from penetrating beyond a certain depth into the handle. The holes are then filled with silver or gold wire, which is either filed and polished off level with the general surface, or allowed to project as small studs.

CYANOGEN, a gaseous compound of carbon and nitrogen, (NC_2, or Cy,) named from *κυανος*, *blue*, and *γεννάω*, *I generate*, on account of its being necessary to the formation of *Prussian blue*. It is interesting as forming a perfect type of a salt-radical. It may be prepared by heating in a small glass retort cyanide of mercury, well dried and powdered: metallic mercury is produced, and cyanogen—a colourless permanent gas, which must be collected over mercury, as it is very soluble in water. It has a pungent and peculiar odour, something like that of peach-kernels or hydrocyanic acid: it is condensed by the pressure of 3.6 atmospheres into a thin colourless liquid. Cyanogen burns with a beautiful purple or peach-blossom coloured flame, producing carbonic acid, and giving off nitrogen.

The interest belonging to this subject is chiefly chemical. Under the head, PRUSSIAN BLUE, the chief compounds of cyanogen used in the arts will be noticed. The compound of hydrogen and cyanogen, cyanide of hydrogen, or hydrocyanic or prussic acid, (CyH,) is one of the most deadly poisons known.

CYCLOID (from a Greek word signifying, *like a circle*), a term not very accurately applied to a curve which is traced out by any point of a circle rolling on a straight line. As the wheel of a carriage revolves, each nail on the circumference describes a succession of cycloids. The properties of the cycloid will be noticed under PENDULUM.

CYLINDER, (*κύλινδρος*,) a straight line moving round the circumference of a circle, keeping always at right angles to its plane, will describe what is called a *right cylinder;* if the moving line be oblique to that plane, it is called an *oblique cylinder*. The uses and applications of the cylinder and of cylindrical surfaces in the arts are exceedingly numerous and very important.

DAMASCUS BLADES. See SWORD-CUTLERY.

DAMASK, a textile fabric, variegated with figures of flowers, &c., woven in the loom. The manufacture is said to have originated at Damascus, whence the name. See WEAVING.

DAMASKEENING. See SWORD-CUTLERY.

DEALS are boards of fir, above 7 inches in width, and exceeding 6 feet in length. If less than 7 inches wide, they are called *battens*, and if less than 6 feet in length, they are called *deal-ends*. Deals are imported into the United Kingdom from Dantzic, Petersburg, Narva, and many other ports in the Baltic, and from North America; but those from Christiania, the capital of Norway, are the most esteemed. Their superiority is said to depend on their being more perfectly sawed than other deals; but it is really due to the quality of the timber, and the care with which the sapwood and other defective portions of the timber are cut away. See TIMBER.

DECANTATION. In order to separate a fluid from the finely divided solid matter which it may contain, the solid matter is allowed to settle down, and the fluid portion is then removed. This is called *decantation*, and it is in many cases far superior to *filtration*. The fluid may be poured off by hand, and as much as possible removed without disturbing the deposit; but it is usually much better to use a syphon. In the manufacture of smalt, [see COBALT,] the process of decantation is largely resorted to. See also EMERY, &c.

DECLINATION, or VARIATION OF THE MAGNETIC NEEDLE, is the angle which the horizontal needle makes with the geographical meridian of any place. See COMPASS.

DECOCTION. It may be useful, thus early, to describe a few of the processes used in chemistry and the chemical arts for effecting the solution of different substances. When hot water is poured upon a substance, and left to act upon it for a short time, the process is called *infusion;* but when heat is kept up for some time by the application of fire, the process is called *decoction*. The common method of making tea is an example of infusion; and when coffee is boiled we have an example of decoction. When cold or warm water is poured upon a substance, and

it is left to stand for some time, the process is called *maceration*. When a soluble body is separated from an insoluble one by washing, the process is called *lixiviation*. "Suppose it were necessary to separate a salt from a quantity of ashes: a funnel of sufficient size should have the lower aperture stopped by a cork, and should be supported on a stand, so that it may steadily retain its proper position. A few pieces of the ash, of such size that they shall not pass through the neck of the funnel, should be introduced in the first place, to prevent the descent of the matter to be placed over it. Having added pieces rather smaller, until the surface exposed in the funnel is an inch in diameter, the rest should be crushed in a mortar to a coarse powder, or rather to small pieces or grains, and put into the funnel above that previously arranged. If the substance be such that it will not afford lumps of sufficient size or strength to remain in the neck of the funnel and support the rest, then its place should be supplied by some pieces of broken glass, which may be continued to the height before mentioned, and which, while they support the substance, afford abundant passages for the fluid when required. Being thus far arranged, hot or cold water is to be poured into the funnel, according to circumstances, its quantity being such that it will just cover the mass. The whole is to be left in that state for a time proportionate to the solubility of the substances present. The water which has penetrated the fragments will gradually dissolve the salts, and forming a heavy solution, will descend in the free spaces, changing situations with the water not yet saturated. In this way a solution will be produced, of much greater strength below than above, and the upper part of the mass will be washed almost perfectly at the first operation. When sufficient time has been allowed, according to the quantity and nature of the salt, and the manner in which it is enveloped, the cork beneath should be withdrawn, and one-half or two-thirds of the solution suffered to run out gradually, not hastily, lest greater disturbance of the solid matter in the funnel be occasioned than is necessary or advantageous. The cork is to be replaced, fresh water added above, so as not to disturb the arrangement; and being left as before for a time, the second solution should then be withdrawn, and this operation repeated till the water which passes is perfectly free from salts, or contains so little as to make further attention unnecessary." [1]

DECOMPOSITION, the separation of a compound body into its component parts, either spontaneously or by chemical agency. Thus the decomposition of sulphate of iron furnishes sulphuric acid and oxide of iron as its proximate elements, and sulphur, oxygen, and iron as its ultimate elements. By decomposition substances are produced whose properties are essentially distinct from those of the compound. Such is not the case by mere mechanical action, for if a compound be reduced by grinding or other mechanical means to an impalpable powder, its chemical properties still remain unchanged. See ANALYSIS.

(1) Faraday: "Chemical Manipulation," Section VI.

DEFLAGRATION is the sparkling combustion of substances without violent explosion, as when charcoal or sulphur is thrown into melted nitre. Glass-stoppled jars, used in the lecture-room, for showing the combustion of different bodies in certain gases, such as phosphorus, sulphur, charcoal, &c. in oxygen, protoxide of nitrogen, &c., are called *deflagrating jars;* the substance to be burnt is inserted by means of a small metal spoon called a *deflagrating spoon.*

DELF, or DELFT, a kind of coarse porcelain originally manufactured at Delft, in Holland. It has been superseded even in Holland itself by the superior manufactures of England and the improved taste introduced by Wedgwood in the making of pottery.

DELIQUESCENCE. Salts which gradually dissolve, or *deliquesce*, by attracting moisture from the air, are called *deliquescent* salts: such are carbonate of potash, acetate of potash, chloride of calcium, &c. Other salts, which give out moisture to the air, are called *efflorescent* salts: thus sulphate of soda, or Glauber's salts, by exposure, spontaneously parts with its water of crystallization, loses its transparency, and crumbles down into a white powder.

DENSITY. The proportion of the quantity of matter to the magnitude is called the *density* of a substance. Thus if of two substances one contain in a given space twice as much matter as the other, it is said to be twice as dense. The density of bodies is therefore proportionate to the closeness or proximity of their particles; and the greater the density, the less the *porosity*. See SPECIFIC GRAVITY.

DETONATION, an explosion accompanied by noise. A stout glass tube used in the analysis of gases by firing them with the electric spark is called a *detonating tube*, and the process of firing is called *detonation*. See EUDIOMETER.

DEXTRINE. See BEER—STARCH.

DIAMOND. See CARBON.

DIAPER, a sort of fine flowered linen, used chiefly for table-cloths, napkins, &c. See WEAVING.

DIASTASE. See BEER.

DIE-SINKING. The operation of hardening is so intimately connected with the preparation of dies, and the multiplication of engravings thereby, that we propose to include our remarks on the subject under HARDENING and TEMPERING.

DIGESTER, a boiler, invented by Papin, closed by a tightly fitting cover, which is held down by a screw *s*, Fig. 710: this cover has two openings, one of which is closed by a stopcock *c*, and the other is furnished with a valve *v*, pressed down by a weighted lever, *l w*. The weight of course acts with greater or less power, according as it is further from or nearer to the fulcrum. This valve is forced open when the pent-up steam has acquired a certain amount of tension, and a portion of it escaping, the temperature and consequently the elasticity of the steam are diminished and the danger of explosion avoided. In Fig. 710, a portion of the side is represented as broken away, in order to show the arrangement of the valve, &c. A common form of digester is called an *autoclave*, Fig. 711, on account of the lid being

self-keyed, whereby it becomes steam-tight by turning it round under clamps or ears at the sides. The use of the digester is to subject certain articles of food, &c. to higher temperatures than can be attained

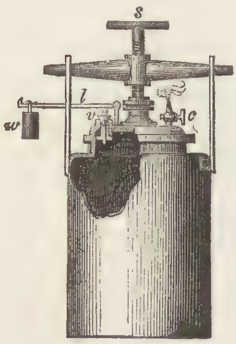


Fig. 710.

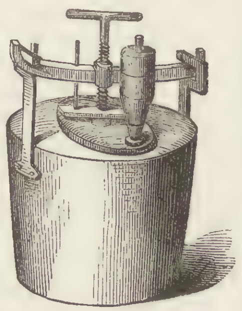


Fig. 711.

when the surface of the boiling liquid is exposed to atmospheric pressure. [See Ebullition.] The increased temperature of water thus produced enables it to separate the gelatine from the phosphate of lime of bones; but the soup made from this gelatine has often an empyreumatic and ammoniacal taste. See Bone—Gelatine.

DIMITY, a stout cotton cloth ornamented either with raised stripes or figures, and employed white for bed and bed-room furniture.

DISTILLATION, a process by which one body is separated from another by means of heat, in cases where one of the bodies assumes the elastic form at a lower temperature than the other: this first rises in the form of vapour, which is received and condensed in a separate vessel. When the vapour condenses in the solid form, such as sulphur, calomel, &c., the process is termed Sublimation. [See Alembic—Camphor—Sulphur.] In this case, the substance to be distilled is usually placed in the lower part of the vessel to which heat is applied, and the vapour rising to the upper and cooler part adheres to it; or an upper vessel being inverted over the lower one, the vapour is condensed within it in the form of a solid cake. When, however, the condensed vapour is obtained in the liquid form, the arrangements are different. The vapour must be preserved in its elastic form up to a certain height, at which the neck of the vessel turns by a sharp curve or an elbow, so that after the vapour has been condensed into the liquid form it descends as quickly as possible. The height of the elbow above the point where the heat is applied, must be only just sufficient to prevent the mass below from boiling over the neck. When the neck of the lower vessel is of great length, the escape of heat must be prevented either by giving it a polished surface, or by covering it with some non-conducting body. The vessel used for generating the vapour, if of large size, is called a *still.* Distillation as carried on by the chemist is usually by means of *retorts,* and the vessel that receives the distilled matter is called a *receiver;* this is perhaps the most simple method of distilling; but it can generally be conducted only in a small way, and when the vapour is easily condensible or when a moderate heat is applied.

Fig. 712 shows a common laboratory arrangement for distillation with a glass retort and receiver. In order to produce a complete condensation, the neck of the retort is covered with linen or bibulous paper, kept constantly wet by cold water dripping upon it

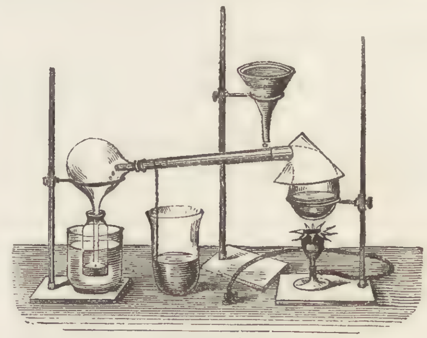


Fig. 712. Faraday's arrangement.

from a funnel or filter: a few threads of twisted tow draw off this water into a basin. The contents of the retort are vaporized by means of the gas-flame; and the vapour passing along the neck may be wholly or partially condensed: any vapour which escapes condensation passes into the quilled receiver, where it is condensed; the bottle containing the distilled product being surrounded with water, or, if necessary, with a freezing mixture.

Liebig's condenser, shown in Fig. 713, consists of a slightly conical glass tube, 18 or 20 inches long,

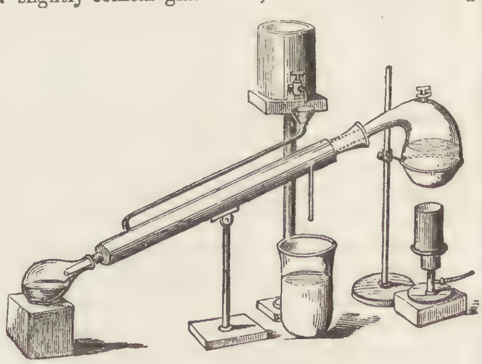


Fig. 713. Liebig's arrangement.

and of a diameter of about 1½ or 2 inches at one end and an inch or less at the other: this is enclosed water-tight in a wider and shorter metal tube, to the lower end of which is attached a funnel supplied with a small current of cold water from a cistern above. As the cold water enters the bottom of the tube, it gradually ascends, and becomes warmed by condensing the hot vapours; and having performed its useful office of keeping the tube cool, it drips or flows off, according to the supply from the cistern, by the hanging tube. The whole arrangement will be evident from an inspection of the figure.

The still is usually so arranged as to present a large surface to the fire. For this purpose it is commonly

made in the form of a frustum of a cone, the base being as large as it can conveniently be made, and the height small. The neck should be wide enough to convey away the vapour as fast as it is formed: the height of the neck must be regulated by the nature of the substance. If it be mucilaginous, such as the wash from which spirit is distilled, the neck should be longer, to prevent its boiling over. The end of the descending part of the neck is inserted into a spirally twisted pipe called the *worm*. The worm is continued in a worm-tub, about 6 or 8 times the capacity of the still. The worm enters on one side of the tub at the top; it then passes spirally in about 6 or 8 convolutions to the bottom, where it comes out of the side in order to discharge the liquid arising from the vapour condensed within it by means of the cold water with which the tub is filled. The water is kept cold in the tub by the warm water flowing away from the top whilst a supply of fresh cold water is admitted at the bottom. It is of importance to keep the worm as cool as possible, because the object is not merely to condense the vapour, but to cool the liquid resulting from it, in order that it may be less liable to evaporation after coming over. Fig. 714 shows a common form of still, in which S is

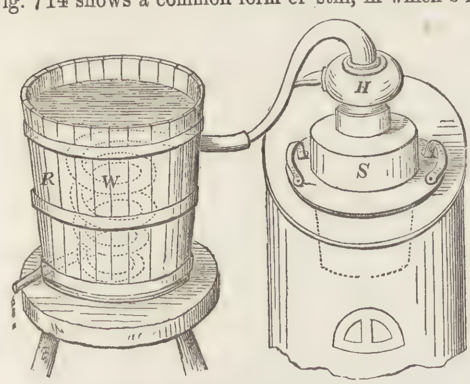


Fig. 714 THE COMMON STILL.

the still, H the head, W the worm, and R the worm-tub or refrigerator.

The arrangement of the fire for heating the still is of importance. The fire should be so placed upon a grate that a due supply of air be admitted to excite a vigorous combustion: no air should be supplied but through the grate; and the quantity of heat will be greatest when the air which enters is not more than sufficient for the combustion; an excess only serving to cool that which the fire had heated. The products of combustion should escape at a point not higher than the level of the grate, so that the heated matter before escaping may impart its heat to the vessel. In the common spirit-still the bottom is circular, and the exterior surface presented to the fire is concave. The fire is placed in the middle of the circle, as in the furnace of Fig. 720: the flame and heated vapour first rise up against the middle of the concave bottom, then move towards the periphery of the circle, and descend as low as the level of the grate, and enter the flue through a narrow neck, which extends through the whole periphery of the circle, and which opens into the flue all round. This narrow aperture prevents the rapid escape of the heated vapour, and allows it to be expended on the vessel.

The process of distillation is exceedingly important in a manufacturing point of view, the business of the distiller being to prepare the enormous quantities of ardent spirits which are consumed in this country and exported. The processes of the distiller preparatory to the act of distillation resemble in many respects those of the brewer. [See BEER.] He prepares a saccharine solution, or wort, and sets it fermenting by the aid of yeast; but instead of allowing the alcohol thus formed to remain in the liquor, as in the case of malt liquors, he separates it by distillation. In all the varieties of ardent spirits, alcohol, formed by the fermentation of sugar, is the intoxicating principle: the aroma or peculiar flavour which distinguishes one spirit from another seems to be due to the presence of an essential oil derived from the substance employed to furnish the saccharine solution. Thus the sugar-cane yields an oil which imparts the peculiar flavour to rum, and rum is obtained from the refuse of cane-sugar in the West Indies. The grape yields an oil which flavours brandy, and brandy is obtained by distilling wine: it is made in large quantities in France, Spain, and other wine countries. Gin, whiskey, &c., are obtained from malt or from the raw grain; the starch, which forms so large a portion of barley, being converted by the action of warm water into sugar, and this into alcohol. Milk contains a saccharine substance, known as *sugar of milk*, capable of forming alcohol by fermentation: the Tartars manufacture from mare's milk an ardent spirit named *koumiss*. Arrack is prepared from the juice of the coco-nut. [See Coco.]

The manufacture of ardent spirit, as conducted in this country, from grain, as in the preparation of whiskey,[1] comprises four principal processes: viz. 1, mashing; 2, cooling; 3, fermenting, and 4, distilling. The grain used is barley, only a portion of which is malted, in consequence of the duty on malt.

1. *Mashing.*—The barley is ground to a fine meal, and the malt is crushed between rollers.[2] Dr. Thomson gives an example from the Scotch distillers, (who have long conducted this branch of manufacture with great skill and success,) in which the proportions are 40 bushels of barley and 20 of malt. The mash-tun is of cast-iron, and the water, measuring 700 or 800 wine gallons, is let in at the temperature of 150°. The mashing is continued from 1 to 4 hours, either by manual labour or machinery; the longer time being required if the proportion of raw grain prevails. To keep up the heat, about 500 gallons of water are

(1) The word *whiskey* is said to be derived from the Irish, *usquebaugh*, which is identical with *eau de vie*, or water of life.

(2) Dr. George Wilson, Professor of Chemistry at Edinburgh, informs the Editor that at the Sunbury Distillery, situate about a mile to the north-west of Edinburgh, where grain-whiskey only is made, "the grain employed is in greater part barley, which is ground pretty finely in a mill. To this a certain portion of oats is always added. They are not ground to powder, but only crushed, or, as the distillers call it, *rolled*, and by their large grain they prevent the barley meal from clogging and caking into a mass. A small quantity of malt is added, sufficient to saccharify the starch of the barley and oats, and the fermentation is managed in the ordinary way."

admitted at intervals, at temperatures varying from 190° to 205°. The mashing being completed, the whole is left for about 2 hours for *infusion*, as the distillers term it. During this time the grains sink, leaving the liquid but muddy wort above. A considerable portion of starch remains unaltered; but the wort gradually increases in sweetness from the beginning to the close of the operation. The wort is drawn off, not as in making beer, at the bottom, because it will not pass through the sediment of barley meal: it is drawn off from the top by a tube pierced full of holes, and rising at one corner of the mash-tun as high as the surface of that vessel. The quantity of wort does not exceed one-third of the water employed; the 1,200 gallons yielding only 400 gallons of wort. To prevent the loss of the remaining two-thirds of the wort, about 500 gallons of water at 190° are let in, and the whole, being well mixed, is left for an hour and a half to *infuse*, and it is then drawn off. The grains, having been deprived of the greater portion of their starch, now part more freely with the water; and in order to carry off everything soluble, about 800 gallons of boiling water are let in upon the grains: the whole is stirred up during 20 minutes, and left for infusion about 30 or 40 minutes. The weak wort which is drawn off is used for mixing with the meal and malt in the next brewing, or, being boiled down to the requisite strength, it is mixed with the first and second worts in the fermenting vessel. Some distillers even make a fourth mash with boiling water, and use the wort instead of pure water in the next day's brewing.

It is important that the distiller should be able to regulate the strength of his worts with precision, as the duty is regulated thereby. The quantity of spirit from 100 gallons of fermented wort is required by law to be 14 gallons: at any rate, the Scotch distillers pay that duty, whether they produce it or not. According to Dr. Thomson, 14 gallons of spirit of the specific gravity 0.90917 from 100 gallons of wort requires the original strength of the wort to be at least $70\frac{1}{3}$lbs. per barrel. With the above quantities of grain, malt, and water, the first worts will be of the strength of about 73lbs. per barrel; the second worts 50lbs. per barrel, and the two, when mixed, 62lbs. per barrel.

The distiller has been for a long period so much fettered by excise regulations as to have had no opportunity of varying and improving his manufacture. The illicit distiller, unimpeded by the restraints of law, has been able to produce a better article, by using malt without any admixture of raw grain: it is also said that the superiority was partly due to the slow mode of distillation adopted by the smuggler. This superiority, perhaps further recommended by its greater cheapness, would be sure to be appreciated among a whiskey-drinking people: the illicit distiller would therefore be favoured and protected, and thus the morals of the people, the revenue, and the regular manufacturer, would all suffer in consequence of injudicious regulations on the part of the government. Of late years, however, the distillers have been allowed to distil from malt at nearly the same rate as they formerly did from raw grain, and hence the high reputation of smuggled whiskey has declined, and with it the occupation of the smuggler. The restrictions under which the distillers were placed were said to be necessary in order to ensure the payment of the duty on the spirits actually distilled. But, as Dr. Thomson suggests, the duty might be levied with as much accuracy, though all restrictions on the strength of the wort were removed. "From a number of experiments, conducted on a large scale, we conclude that the fermentation, however successful, is capable of decomposing only four-fifths of the whole saccharine matter contained in the wort. Further, we find that, for every pound of saccharine matter decomposed by the fermentation, there is formed half a pound of alcohol, of the sp. gr. 0.825. Now, every gallon of spirits of the sp. gr. 0.90917, or 1 to 10 over proof, contains 4.6lbs. of alcohol of the sp. gr. 0.825. To form a gallon of spirits, then, of the sp. gr. 0.90917, there is required the decomposition of 9.2lbs. of saccharine matter. But as only four-fifths of the saccharine matter present are decomposed, we must increase 9.2 by a fifth, which will raise it to $11\frac{1}{2}$lbs The rule, therefore, for levying the duty on the distillers would be this:—Ascertain by the saccharometer[1] the strength of the wort, or the number of pounds avoirdupois of saccharine matter which it contains, and for every $11\frac{1}{2}$ of these pounds charge the duty upon one gallon of spirits. This would be no hardship upon the distiller. He would find that the flavour, and consequently the value of his spirits, increases as he diminishes the strength of his wort, and that the produce of spirits from the same quantity of grain increases also as he diminishes the strength of his wort."[2]

2. *Cooling.*—As wort from raw grain tends to acidity sooner than wort from malt, the distiller cools his worts as quickly as possible. They are removed from the underback to the coolers, consisting of shallow wooden vessels, in the upper part of the building: the depth of the sheet of wort may be 1, 2, or 3 inches, according to circumstances. Another method of cooling is by passing the wort through pipes immersed in a stream of cold running water. There is no evaporation in this method, as there is in the former, and consequently the strength remains the same after cooling as before. This is of some disadvantage to the distiller, as the duty is levied on the bulk and not on the strength of his worts. During the cooling there is a considerable deposit of flocky matter, consisting chiefly of starch: this is swept into the fermenting tun, and is supposed to assist the fermentation. Winter is the usual season for the operations of the distiller, as it is difficult in warm weather to keep the fermenting room sufficiently cool. The worts are let down at about 70°, and the second worts at 60° or 65°.

3. The process of *fermentation* is the most important part of the manufacture, as on it the profit or the loss

(1) See Beer, *ante*, p. 117, Fig. 111.
(2) Encyclopædia Britannica; art. *Distillation*.

of the manufacturer chiefly depends. The yeast, which is supplied by the porter and ale brewers, must be of the best quality. For the quantity of wort already indicated, about 27 gallons of good yeast are required, or 36 gallons if the yeast be of inferior quality. A portion only is first mixed with the wort, other portions being added on the second, third, fourth, and even on the sixth days. Some distillers add 9 gallons every day for 4 days. The fermentation may last 9, 10, 11, 12, or even 13 days. During the first 5 days the fermenting tuns are left open at the top, or are only partially covered; but on the sixth day they are shut up for the purpose of confining the carbonic acid gas, which in escaping carries off a portion of alcohol, and thus occasions loss. It generally happens, however, that the fermentation is nearly over before the tuns are shut, so that the loss of alcohol by the escape of carbonic acid has already occurred. The presence of the carbonic acid is also supposed to promote fermentation, and by preventing its ready escape the attenuation of the wort is supposed to be greater than it otherwise would be. This may be true, because it is known that carbonic acid may be substituted for yeast as a ferment. The distiller does not collect any yeast from his worts, but beats it all into the liquor; he supposes that by collecting it the fermentation would be less complete, and the alcoholic product diminished. During the fermentation the temperature of the wort rises considerably; often as much as 20° or 25°, so that if let down at 57° its temperature may rise to 78° or 82° about the fourth or fifth day. The time when this maximum is attained is, however, uncertain, and depends to a great extent on the quality of the yeast employed; and it is the uncertain character of the yeast which makes the difficult business of the distiller still more difficult. As the fermentation proceeds, the specific gravity of the wort diminishes, owing to the decomposition of the sugar and its conversion into alcohol and carbonic acid. In all cases of fermentation, in a Scotch distillery at least, one-fifth of the whole of the saccharine matter escapes decomposition, in consequence of the anti-fermenting power of the alcohol evolved. Hence it is more profitable for the distiller to operate with weak worts than with strong ones, for the weaker the original wort, the less will be the quantity of the saccharine matter which escapes decomposition. When the heat is at its maximum nine-tenths of the whole attenuation has been completed. The object of the distiller is to render his *wash*, or fermented wort, as light as water, and he will be able to do so unless his yeast be of bad quality.

When yeast cannot be readily procured, a substitute called *bub* is employed. It is prepared by thoroughly mixing together a quantity of meal or flour with a little yeast in a quantity of warm worts and water: the whole being closely covered up, a violent fermentation almost immediately ensues, and in that state it is added to the worts. Should the fermentation be found to lag, some yeast is added; but for revenue purposes the whole quantity of bub and yeast is not allowed to be more than five per cent. on the quantity of worts previously collected. This allowance is generally found to be more than sufficient.

Dr. George Wilson informs the Editor that at the Sunbury Distillery the cost of yeast is 50*l*. per week. He says that the Scotch whiskey distillers trust to the care bestowed by the ale and porter brewers, that the yeast is sufficiently often varied and otherwise in good condition; the brewers exchanging yeast with each other at intervals,—a practice which is necessary to prevent the yeast from deteriorating. The brewers mingle the yeasts of different breweries together until they produce a liquid of a certain thickness and strength, of which they judge by an empirical rule. They seem to be indifferent as to the source of the yeast, so far as beer, ale, or porter are concerned; but they aim at securing it of standard strength, by mixing the thin and the thick, the active and the sluggish.

A practical writer thus describes the phenomena of fermentation:—" Soon after the yeast or bub has been added to the worts, fermentation commences: its first effects are indicated round the sides of the back by the appearance of a scummy-looking matter on the surface of the worts, and the emission of small bubbles which contain carbonic acid gas. The temperature increases as fermentation advances: its progress is rather slow at first, but gradually increases, and after some time proceeds with prodigious rapidity. Large bubbles of carbonic acid gas escaping set the whole in motion, as if in a state of violent ebullition; a large quantity of froth collects on the surface of the liquor (which is now called *wash*), which often accumulates with such rapidity that several men are required to beat it down with oars, to prevent its spilling over the top; indeed, on some occasions, the beating on the top has been found ineffectual, and the distiller forced to pump a portion of the wash up to the coolers, to lower its temperature, and then return it, after which the process proceeded at a moderate rate; and in all cases, towards its close, the rate of fermentation gradually diminishes, and the temperature decreases, till at last the wash acquires the temperature of the tun-room, and remains quiescent." [1]

Dr. George Wilson, in a letter to the Editor, thus notices the fermenting-tuns of the Sunbury Distillery: " I thought of Priestley as I stood at the small doorway of one of the immense vats, from which the mixed vapour of alcohol and carbonic acid was issuing, extinguishing candles held near it, and falling with a blinding anæsthetic weight on the breathing organs of all respiratory animals near it. Professor Simpson tells me that he thinks the intoxicating power of champagne is owing to the vaporization of alcohol along with carbonic acid. I always thought the theory a true one, but I realized its truth to-day. A single whiff of the vapour, gushing forth in sufficient volume to *blow* upon the face, was enough to make a friend and myself spring back with our hands on our faces. We did not try a second draught."

(1) Thomson's "Records of General Science," vol. ii.

The wash-backs or fermenting tuns are of large size, to prevent the heat from being dissipated; and they are only partly filled, to prevent the wort from frothing over when it is in full fermentation. Some distillers, however, fill the tuns almost to the top, and close the mouth tightly with a lid, from which a tube passes to an open vessel placed above the tun, so that when the liquor swells by fermentation, it passes up the tube into an open vessel, and runs down again when the fermentation subsides. The fermenting tuns are sometimes made in the form of a cone standing on its larger base, and either round or oval, but sometimes they are square: some are of wood, others of iron. Iron, being a better conductor of heat than wood, has this advantage, that either hot or cold water may be applied in an outside case, to regulate the temperature of the wash contained in the back.

4. As soon as the fermentation is over, the wash is distilled. The stills formerly used were very large and deep, and a whole week was required to complete the process in one still. About the year 1787, however, an alteration was made in the method of levying the duty, with the view, as it was supposed, of making it more difficult for the distillers to evade it. The duty was, accordingly, levied on the distillers by a licence paid at the commencement of the season on every still in use, according to its capacity. The quantity of spirits which a still of known dimensions could produce in a year was calculated, and the sum paid for the licence was laid on it accordingly. This plan saved the excise officers much trouble, but the distillers took advantage of it with very remarkable results. The very next year after the plan came into operation, a firm in Leith diminished the height and increased the diameter of the bottom of their stills, so that by exposing a much larger surface to the action of the fire they could distil off the contents in a few hours instead of once a-week. In this way, by producing a large quantity of spirits from a very small still, they paid a much smaller amount of duty than their neighbours. A discovery so important in its pecuniary results was not likely to remain a secret very long. After some months the practice was adopted by other distillers, and it soon became general in Scotland. Parliament met the case by increasing the licence duty; this was done several times, but after each increase, the manufacturers worked their stills quicker and harder than ever, so that they, and not the revenue, were the gainers. In 1799 a Committee of the House of Commons was appointed to investigate the subject, and in consequence of their report the licence was laid on the distiller on the supposition that he could discharge his still every 8 minutes during the whole season that the manufactory was in operation. These 8 minutes were, however, considerably shortened by the distiller, but the saving in time was accompanied by such an enormous waste of fuel, as to render the additional profit doubtful. In 1815, the last year of the licence duty, a still of 80 gallons could be completely distilled off, emptied, and ready for a new operation in $3\frac{1}{2}$ minutes, and in some cases 3 minutes; and a still of 40 gallons in $2\frac{1}{2}$ minutes. At this time, however, a change was made in the excise laws; the licence duty was abolished, and the whole duty was levied as in England on the wash and the spirit produced. After this the slow process of distillation was again adopted; not so slow as before, for the quick method left some of its traces behind, and the new stills were, accordingly, made to resemble the quick ones in the large diameter of their bottoms, and their comparative shortness compared with the stills used in England.

Various forms of distillatory apparatus are used in Scotland, the principle of which will be described presently. We will first speak of the operations as conducted by the common still, before we refer to more complicated forms of apparatus.

When the wash has been put into the still the top is fixed down and heat applied. As spirit is more volatile than water, it passes over first in the form of vapour, and is condensed into a liquid in passing through the worm. The first portions are very strong, but the strength diminishes as the process proceeds; for the same heat which drives over the vapour of alcohol also drives over some vapour of water, and the two being condensed together mingle in the liquid state. At the beginning of the process much more alcoholic than aqueous vapour passes over, and towards the end of the process much more aqueous than alcoholic. When the liquid that comes over is as heavy as water, or nearly so, the process is stopped. The strength is tried every now and then by means of a small hydrometer, and when a certain mark on the instrument coincides with the surface of the liquor, a cock at the bottom of the still is opened, and the spirit wash is let off. It is a muddy, brown liquor, still containing undecomposed saccharine matter: it is used as food for cattle; they are very fond of it, and fatten quickly upon it.

At the commencement of the operation the still is apt to boil over. To prevent this it is usual to throw a bit of soap into the wash: this is partly decomposed, and the oily matter spreads on the surface and forms a thin coat, which breaks the large bubbles when they reach it, and thus prevents the wash from swelling beyond the proper bulk. Spirits may sometimes be met with having the nauseous taste of soap: this arises from morsels thereof having been accidentally forced into the worm, and afterwards dissolved by the spirit.

The weak spirit obtained by the first distillation is called *low wines* in Scotland. Its specific gravity at 60° is about 0.978; it contains about one-fifth alcohol of the sp. gr. 0.825, the remaining four-fifths being water. The *low wines* are distilled a second time by a process called *doubling;* the first portion that comes over is a milky liquid; this is called *foreshot;* it is loaded with oil, and has a disagreeable taste; it is returned back to the low wines and distilled again. When the spirit begins to run transparent from the end of the worm, it is allowed to flow into a receiver prepared for the purpose. When the specific gravity

has reached a certain point, as determined by the hydrometer, the spirits are no longer allowed to flow into the receiver, but into another vessel, and the distillation is continued until the sp. gr. of water is nearly attained. This third portion is called *faints;* it is mixed with the low wines and distilled again. The distillation of the low wines is continued till the whole of the alcohol is brought to that degree of strength which is adapted to the market. The strength at which the duty is levied on them is 1 to 10 above hydrometer proof; this corresponds to the sp. gr. 0.90917. The distillers are not allowed to send out spirits of greater strength than this, or of a strength under 1 in 6 below proof, or of sp. gr. 0.9385.

The Scotch distillers use the best English barley for malting, for this when malted yields more spirits than raw grain: but when raw grain is used, big answers the purpose as well as barley, and is more economical.

It has already been stated, that in addition to the alcohol which passes over with greater facility than water, there are other volatile matters furnished by the vegetable substance from which the fermented liquor is procured. These are essential oils, which vary with the kind of fermented liquor employed. When they are from wine or from the wash made from sugar, their flavour and aroma are agreeable: the oils furnished by malt and grain are, however, very disagreeable, and when the old form of still is used, it is the business of the *rectifier* to remove them.

The rectifier procures his spirit from the distiller in the state of what is called *raw spirit;* this contains all the volatile impurities which pass over in the first process. The rectifier purifies his spirit by a method of his own, but his distilling apparatus by the old plan is in every respect similar to that used by the distiller; only he applies his heat with greater caution. It does not always happen that the rectifier removes the offensive aroma from the raw spirit; he may substitute another which overpowers the original: this is generally done in the different kinds of gin and other compound cordials. In some cases when the spirit is very weak and the essential oils are abundant, the water exerts a greater attraction for the alcohol than the alcohol does for the oils: a portion of the oil thus becomes free, and gives the liquid a milky appearance. The oils are in such case separated by adding alkalies, which forming soapy compounds therewith do not pass over with the spirit at the moderate heat employed in the rectification. By the addition of acids the oils are converted into resinous substances, by which they also become less volatile.

Whiskey and gin are by far the most important varieties of spirits produced by British manufacture. The Dutch are celebrated for the manufacture of gin, Geneva, or Hollands. According to Dr. Thomson, the following is the process:— 112lbs. of barley-malt and 228lbs. of rye-meal, are mashed with 460 gallons of water at 162°. After infusing a sufficient time, cold water is added until the gravity of the wort is reduced to 45lbs. per barrel. The whole is let into a fermenting back at 80°: half a gallon of yeast is added; the temperature rises to 90°, and the fermentation is over in 48 hours. The wash is attenuated until the gravity is about 12 or 15lbs. per barrel. Both the wash and grains are then put into the still; the low wines are distilled off; these are redistilled, and the product is rectified. A few juniper berries and some hops are used to communicate a peculiar flavour to the spirit.

Instead of referring to the article Still for a detailed description of that most important apparatus, it will be desirable to introduce what we have to say on the subject in this place.

We have seen that when a mixed liquid, consisting of two ingredients of different degrees of volatility, is exposed to the action of heat and made to boil, the more volatile ingredient passes over first, and can thus be separated more or less perfectly from the less volatile portion. If the difference between the boiling points of the two liquids be not very great, the separation is imperfect, as, for example, in a mixture of strong alcohol and water, the boiling point of the alcohol being about 176°, and that of the water 212°. When this mixture begins to boil, the vapour of alcohol which comes over brings with it a portion of the vapour of water, so that the distilled liquid is not alcohol, but a mixture of alcohol and water. At the commencement of the process, the boiling point of the mixture is something intermediate between the boiling points of the two liquids when separate, *viz.* 176° and 212°; it is probably about 190°, but as the alcohol distils over, the temperature gradually rises until all the alcohol has distilled over, and then it will be 212°. Hence it will readily be seen that the first portions which pass over will contain most alcohol, and the last portions most water. As the hot vapour passes into the worm (Fig. 714), it gradually cools in descending; the water which surrounds the worm being hottest at the top, gradually cooling in the middle, and becoming cold at the bottom, the differences of temperature in the worm varying from the temperature of the boiling liquor to that of the atmosphere. Now, as the alcohol and the water differ in volatility, they differ also in condensibility; as the liquids are converted into vapours at different temperatures, so the vapours are condensed into liquids at different temperatures; and as these different temperatures exist at different parts of the worm, it follows that the vapour of alcohol is condensed at one part of the worm, and the vapour of water at another part. The vapour of water begins to condense as soon as it enters the worm, because it is immediately reduced to a lower temperature than 212°, which is necessary to its vaporiform state. The vapour of alcohol, however, can exist at a much lower temperature than that of water, so that in those parts of the worm where the vapour of water is being condensed, the vapour of alcohol retains its elastic state, and passes on to that lower part of the worm where, the temperature being below 176°, it necessarily becomes condensed. In the ordinary construction of the worm, however, the water condensed in the upper part of the tube flows down and mixes with the

alcohol condensed in the lower part of the tube, and the separation which has been effected in so refined and delicate a manner by a natural process, and which it is one of the great objects of the distiller to accomplish, is defeated in consequence of the defective construction of the still. To remedy this, the liquid condensed by the worm was distilled by the rectifier, as already stated, a second, a third, and even a fourth time, the object being to separate the water which actually had been separated by the worm in the first process; and thus time, labour, fuel, and apparatus were engaged in 4 operations when, by a more scientific arrangement, one operation might have sufficed. Various attempts had been made to remedy the defect, without success; some distillers tried to shorten the time in which a given quantity of spirit of the usual strength could be obtained; others attempted to shorten the time, and also to obtain a stronger spirit; a third set of improvers endeavoured to economise the heat; a fourth set, to render the apparatus self-acting, and constant in its operation. With respect to the shortening of the time, the Scotch distillers, as already noticed, produced the most extraordinary effects. Taking advantage of the method by which the duty was levied on the capacity of the still, instead of on the quantity of spirit produced, they endeavoured to improve their stills so as to make them furnish a larger quantity of spirit. The distillers found that the more shallow the still, the broader the bottom, and the larger the furnace and supply of fuel, the more rapid was the distillation. After various forms of still had been tried, one was invented by Mr. Millar of a capacity equal to 16 gallons of wash, or 24 gallons of singlings, and so judicious were the arrangements, that the still might be charged, run off, and discharged nearly 22 times in an hour. In this still steam was allowed to pass off at as many points in the shoulder of the still as possible; a fly kept in constant motion in the head of the still broke the froth, and prevented the still from running foul; an agitator kept the boiling wash in constant motion, so as to prevent the deposition of any sediment, and if any sediment formed it was prevented from being burnt by the fierce heat by a piece of machinery which constantly scraped it up from the bottom.

An adaptation of this still by Sir Anthony Perrier, of Cork, is shown in Fig. 715, in which the liquid to

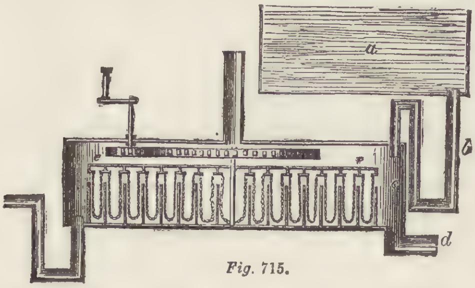


Fig. 715.

be distilled is made to flow gradually and continuously over the heated surface of the boiler, while it continues to part with its alcohol. The bottom of the boiler is divided by concentric partitions, which stand up sufficiently high to prevent the liquor from boiling over: these partitions have openings from one to another at opposite sides, so as to make the course a sort of labyrinth. *a* is a reservoir of liquor prepared for the operation, *b* a pipe descending therefrom, and conducting the liquor into the boiler at *c*, which is the commencement of the labyrinth, in flowing through which it progressively traverses the whole surface of the bottom, so that the full effect of the fire is exerted upon small portions of the liquid, which causes the evaporation to proceed with great rapidity. The spent liquor passes off by the discharge-pipe *d*. A deposit is prevented from forming and burning by means of the chains suspended from the bar *e e*, which is supported by a centre shaft set in motion by means of a toothed wheel and pinion. These chains hang in loops, and fall into the spaces between the partitions, to sweep the bottom of the still as the shaft revolves.

In this still the great defect already noticed was not remedied, for the vapour of water and of alcohol condensed at different parts of the worm mingled together at the bottom. Mr. Coffey, a distiller of Dublin, seems to have been the first, in this country at least, to remedy this defect, by inserting in the first and second rounds of the worm two pipes, which, passing down, entered the boiler of the still, so that the vapour of water, being condensed in these first two rounds of the worm, passed down these pipes into the boiler, while the vapour of alcohol, retaining its elastic form, passed on beyond the first two rounds, and condensing in the lower and cooler part of the worm could be separately collected.

The principle of this ingenious still was not new at the time of Mr. Coffey's invention, for some of the early chemists, such as Jean Baptista Porta, Lefevre, and Glauber, had adopted it. The merit of Mr. Coffey's still was in the simplicity with which the principle was applied. In the old forms of still a straight, spiral, or zigzag tube proceeded from the head of the boiler, and at the upper end of the tube was affixed another head, from the side of which proceeded a pipe for discharging the distilled liquor. The watery vapours condensed in the upright tube which proceeded from the head of the boiler, and the alcoholic vapours passing through it were condensed in the upper head, or capital, which in some cases was surrounded by cold water.

It is necessary to refer more particularly to Glauber's apparatus, on account of the important influence which it had on the art of distillation at the commencement of the present century. Glauber died in 1668, but his apparatus, as modified by Woulfe, (who died in 1805,) is much better known by the name of the latter. It consists of a series of close vessels, *a b*, *c*, Fig. 717, placed side by side, connected by tubes, 1, 2, 3, fitting in tight joints, and originating from the top of those which precede in the series, descend to the bottom of those which succeed. Now, the object for which this apparatus is chiefly used in scientific chemistry is for the purpose of impregnating

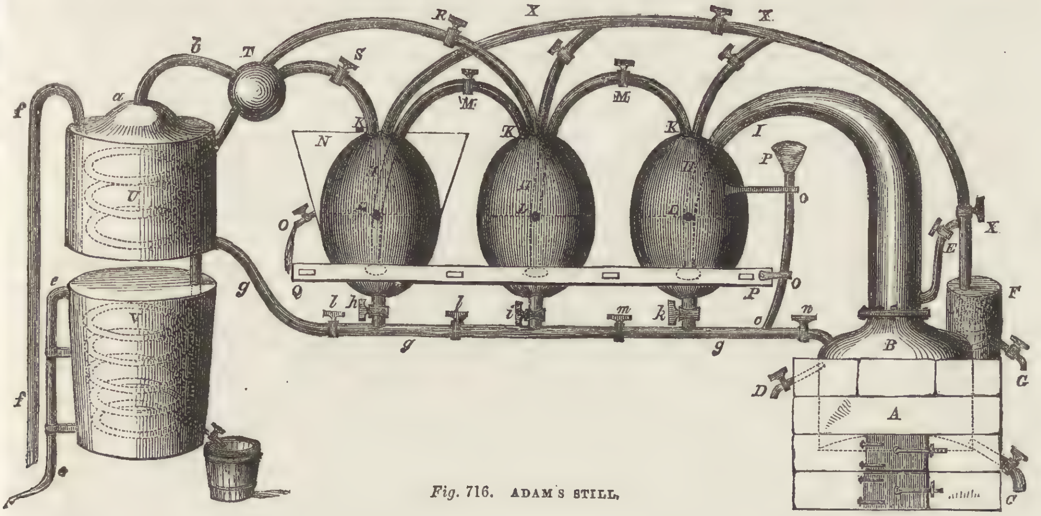


Fig. 716. ADAM'S STILL.

liquids with gases, and as such we shall describe it. Suppose it were required to impregnate a certain quantity of water with muriatic acid gas. The gas is supposed to be delivered into the bottle, *a*, by the tube 1; it is immediately dissolved by the water, but as from the continual additions of gas the liquid becomes saturated, a portion of the gas passes into the upper part of the bottle, and propelling the air before it enters the bottle *b* by the tube 2. Here it acts exactly as in the bottle *a*, and having saturated the water therein, it passes in a similar manner on to a third bottle, *c*, and from that to wherever the tube 4 may lead. The tube *d* is called a *safety tube*, and its use is to admit air into the bottles when the internal pressure becomes less than that of the atmosphere. If, for example, the supply of gas into the bottles *a* and *b* were stopped while solution was still going on; as the water dissolved the gas above it, the atmospheric pressure would force the fluid from the bottle *c* up the third tube into the bottle *b*, and from thence up the second tube into the bottle *a*. This is prevented by the safety tube, which passes through a tight joint into the bottle, and has its lower extremity immersed in the liquid to the depth of half an inch or more. When the absorption of the gas takes place, air passes down the tube, enters the bottle, and prevents the liquid from the other bottles from being forced up the tube. If, on the contrary, the gas accumulates in one of the bottles faster than it is absorbed, its pressure on the surface of the liquid forces a column thereof up the safety tube.

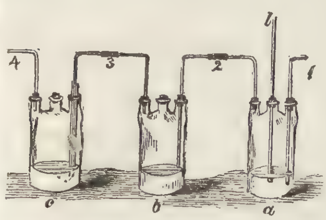


Fig. 717. WOULFE'S APPARATUS.

In the first year of the present century, a Frenchman named Edouard Adam, who is described as "an obscure person, unacquainted with science, and ignorant of the art he intended to improve," happening to be present at a chemical lecture at Montpelier while a Woulfe's apparatus was being exhibited and explained, conceived the happy idea of applying such an apparatus to the distillation of brandy from wine. He immediately set to work and constructed a small apparatus, which after repeated alterations was found to answer the purpose for which it was intended. In 1801 he obtained a *brevet* or patent for his invention for 10 years, and from this time the art of distillation became completely changed, not only in the wine countries of France where brandy is manufactured, but also in other countries where ardent spirits are made. The forms of still are almost innumerable, but the principles which regulated the construction of Adam's still are observed in all, modified only according to the special purpose intended to be answered.

Fig. 716, is a view of Adam's still, which we will describe somewhat minutely. A number of egg-shaped vessels H H H, made of copper, are supported on their small ends by the framing P Q, the upper or large end of each being perforated, we will suppose with two holes, for the reception of copper tubes which connect the vessels together. From the top of the first egg at K proceeds a tube M H, which plunges to the bottom of the second, and terminates in a perforated rose like that of a watering-pot. From the top of the second egg proceeds another tube, which passes to the bottom of the third egg, and so on to the end. The tubes fitting steam-tight in the holes, it is evident that if the eggs be half filled with liquid, air blown through the first egg will bubble through all the eggs and escape at the last. But suppose that instead of air, the vapour from a fermented liquor, such as wine, be passed through the eggs half filled with wine, and that wine is also contained in a still B, to two-thirds of its height as regulated by the cock D, and that this still is heated by a furnace A: the vapour of alcohol mixed with watery vapour will be discharged through the tube I, into the first egg, where both vapours will be condensed and absorbed. The wine in this first egg thus

becomes richer in alcohol than it was, and also becomes heated by the condensed vapours. This wine cannot, however, become as much heated as the wine in the boiler, because containing more alcohol it boils at a lower temperature. The consequence of its boiling at a lower temperature is that alcoholic vapours containing less water will be discharged into the second egg, the wine of which becomes in its turn richer in alcohol than the first, and will boil at a still lower temperature. In like manner the alcoholic vapours from the second egg will enrich the wine of the third egg, and making it strongest of all, it will boil at a still lower temperature, and the alcoholic vapour discharged from it may be passed through a worm U, and condensed. If a weaker spirit is required, the third egg may be dispensed with; this is cut off from the rest by closing the stop-cock M′ and opening the stop-cock R, which connects the second egg with the worm U. If a stronger spirit be desired, a fourth egg may be added, for in every egg alcohol is separated from water, the greater part of which is left behind. According to the inventor, the greater the number of eggs, the better the rectification would be carried on. The last egg is furnished with a cooler N surrounding the upper part, and containing water which as it became heated was let out at O. The worm, however, in which the spirit is finally condensed is not cooled by the presence of cold water in the worm tub, but by cold wine, which becoming heated by the worm is thus prepared for the boiler A; for when the alcohol has been separated from the wine in the boiler and the eggs, the watery residuum is let off by a cock C, and the hot wine from the refrigeratory let in by a tube *gg*. The refrigeratory is then refilled with cold wine. The worm tub containing the cold wine is entirely closed; but at the top is a dome *a*, whence proceeds the pipe *b*, which collects any alcoholic vapours that may be formed in consequence of the heating of the wine in U, and pours them into the globe T, in which the vapours from the eggs are collected before passing into the worm. The large tub V encloses a second worm filled with water, kept cold by constantly drawing off from the top where it is hottest by means of the pipe *e*.

The strength of the spirit in each egg can be proved by means of the tube X X, which proceeds from the last egg and communicates with the small worm F. From the head of the still and also from each egg a tube opens into the tube X, and as each of these branch tubes is furnished with a stop-cock, the vapour from the still or from any one of the eggs can be condensed in the worm F, and the spirit drawn off at G, while all the other parts remain closed.

The wines destined for distillation are kept in a storehouse, and are pumped up into the tub U along the conducting pipe *ff*, which proceeds nearly to the bottom of the tub. The pipe *gg* communicates with the still and the eggs: *hik*, are stop-cocks for continuing or interrupting the communication between each egg and the still for the purpose of discharging it, or with the condensing vessel U for the purpose of filling it. The still and the eggs can also be charged with brandy or with feints by means of the pipe *oo* which opens into *g*.

In setting this still to work the stop-cocks *hik* are closed, and *lmn* are opened, when the wine from U flows into the still, fresh wine being meanwhile pumped up until the still is two-thirds full, as indicated by wine flowing out of D. D is then closed, as also *n*: *k* is opened, and wine flows up into the first egg until it is half full, when it begins to flow out at a tube placed at L: this pipe is then closed, as also the stop-cocks *k* and *m*: *i* is then opened and half filled in like manner, as are also the other eggs except that one which acts as a condenser, which in Fig. 716, is the third egg. No liquor is put into this; but the cooler being filled with water, all the lower cocks are closed and the upper ones opened to afford a free passage to the vapours. The fire is then urged, and the distillation proceeds as already described, the alcoholic vapours traversing the three eggs, condensing in the upper worm, and, being completely cooled in the lower worm, the ardent spirit passes out at the stop-cock, and is received in a proper vessel, which is sometimes a hogshead. In order that the alcohol may not evaporate in passing from the worm into the hogshead, and at the same time to allow the stream to be seen, a glass pipe is attached to the extremity of the worm. The products of the still are received until the liquor is found to diminish in strength: the first hogshead is then removed and replaced with another, to receive what are called the *repasses* or feints, which are again passed through the still. The point at which the operation requires to be arrested is ascertained by condensing some of the vapour in the small worm F, and opening the stop-cock G, some of the spirit is received in a glass: fire is applied to this spirit, and if it does not burn, the process is stopped. This loose and inaccurate method has been of late years superseded by the hydrometer. When no spirit is formed, the fire is extinguished, the residuum is let out, and the still is fresh charged as already described.[1]

Great and decided as was the improvement effected in the art of distillation by Adam's still, yet it was evidently liable to the defect of not being continuous: for as soon as one charge was elaborated, the fire had to be withdrawn, the residue let out, and the apparatus charged afresh, the fire relighted, and so on. This defect was partially remedied in 1805, by M. Isaac Bérard, whose condensing apparatus offered the further advantage of being capable of being adjusted to any existing form of still. The success of this apparatus alarmed M. Adam, who took legal proceedings against Bérard for infringement of patent, but it was clearly proved by the eminent Chaptal, that although the principle of the two inventions was the same, yet that principle was by no means

(1) "Essai sur l'Art de la Distillation," par L. S. Lenormand, Paris, 1811. The reader who wishes to study the art of distillation in greater detail, is referred to one of the cheap and useful Manuels-Roret, entitled, "Nouveau Manuel Complet du Distillateur et du Liquoriste," par Lebeaud and Fontenelle, Paris, 1843.

new, and was applied in a very different manner in the two inventions. In 1808, M. Blumenthal combined the two inventions in a still, in which wine continually flowed in at one part of the apparatus and escaped at another, entirely deprived of its alcohol. Some years later M. Derosne became the proprietor of this apparatus, and further improved it. We will first state the principle of this contrivance, and then describe the apparatus by which it is carried out. A copper boiler is set in masonry with a fire beneath: the mouth of the boiler is fitted with a tall copper cylinder standing perpendicularly over the boiler and fitting closely. About half way up the height of this cylinder and in its axis, a slender tube enters it and discharges a continual but small stream of the wine or wash to be distilled. The wine is prevented from falling down directly into the boiler beneath by means of a number of diaphragms, through which the wine percolates in streams like rain, whereby it presents a large extent of surface to the vapour which passes it in a different direction. In some cases the ascending vapours have to force their way at each diaphragm through a thin stratum of liquid, and they thus undergo a certain amount of pressure. The wine when it enters the cylinder is almost boiling, and while it falls in small showers through the pierced shelves, a copious issue of watery vapour ascends from the boiling copper below. The watery vapour at the temperature of boiling comes in contact with the streams of wine almost boiling: the latter therefore receive heat from the former, and by so doing there is a change of state; the watery vapour, losing heat, falls back as water; and the wine acquiring heat, boils, and its alcohol in a state of vapour rises higher up in the cylinder, where meeting with wine it is absorbed, and a wine richer in alcohol is produced. This more alcoholic wine readily parts with its alcohol in the form of vapour, by the action of heat continually carried up the cylinder. This vapour of alcohol ascending higher meets with more wine, is absorbed, and again set free in larger quantity. At length the portions of wine high up in the cylinder become highly charged with alcohol, and the alcoholic vapours meeting with no more wine, pass on to a worm, where they are condensed into very strong spirit. The worm tub is filled with wine, which in cooling the worm becomes heated itself, and this heated wine flows through the slender tube into the cylinder, where it is distilled as already explained. As this worm is never perfectly cold, the alcoholic vapour which escapes condensation is passed through a second worm, also surrounded by wine, which condenses it completely.

Should the watery vapour which ascends from the boiler into the cylinder, and becoming condensed falls back into the boiler, carry any alcohol with it, the latter is again volatilized; so that the boiler contains nothing but water derived from the wine; for although the boiler had been filled with wine, it soon becomes water by parting with its alcohol. As fast as the boiler fills with water, it is emptied by a cock placed in the bottom. Two boilers are more efficient than one, and when arranged so that a tube proceeding from the head of one plunges to the bottom of the other, they act like two of the eggs in Adam's still. The discharge of wine from the great reservoir is regulated by a ball-cock, and there is a constant supply of cold wine, *first*, to the two worms for the purpose of cooling them, (by which method of heating the wine fuel is economised;) *secondly*, to the distillatory column. Having parted with its alcohol, the watery portion falls into the boilers, whence it is let off entirely deprived of alcohol. The flow of wine being thus perpetual, no time is lost by an interval of discharging and charging. It must also be noticed that when the alcoholic vapours enter the first worm they are condensed; but as the weakest or most watery alcohol condenses in the first rounds of the worm, it is so contrived that this watery portion shall run back by small tubes into the cylinder, where it is re-distilled. The worm at all its rounds is provided with cocks and tubes, by which the portions condensed in any part may be let back to be re-distilled, or they may be all shut, or some may be left open, so as to return the whole or any part into the cylinder. In this way, by means of these cocks, alcohol of any required degree of condensation, within certain limits, can be obtained.

The apparatus by which these complicated effects are produced is shown in Fig. 718. It consists of two boilers A A′, a distillatory column B, a rectifier C, a condenser D, which also serves to heat the wine, a refrigerator E, a reservoir of wine G, which feeds a small cistern F, the supply being regulated by a ball-cock. The boiler A is filled through the pipe H, and emptied by means of the stop-cock R. The height of the liquor in the boilers is indicated by the glass tubes xx'. The pipe Z, proceeding from the head of A, conducts vapour to the bottom of the boiler A′ and thus these two boilers act like two of the eggs in Adam's apparatus. The boiler A′ is heated by the flue of the fire under A. The second boiler is filled by means of the tube H′, and by the cock R′ the contents of the second boiler are transferred to the first. The distillatory column B, and the rectifier C, contain a number of diaphragms, the use of which will be explained presently. The condenser D is a cylinder of copper placed horizontally: it is divided into two unequal portions by a diaphragm, at the lower part of which is an opening for allowing the two portions to communicate: the condenser contains a worm, the axis of which is identical with that of the condenser; this worm commences at M and terminates at O: each spiral of the worm has at its lower curve a small pipe, *a*, connected with a sloping pipe, which conveys the whole or only a portion of the liquid from the worm into the pipe O, or into the rectifier, according as the stop-cocks 1, 2, 3, are opened or shut. At U, V, X, the column can be opened for cleansing when required. L is a pipe which conducts hot wine from the condenser to the distillatory column. The refrigerator E is a close copper cylinder, containing a worm which originates at O, and terminates in the tap below. It is kept filled with cold wine by means

of the pipe I, and when quite full, the wine rises up the pipe K, and fills the condenser D.

This apparatus is set in action by first pouring into the boiler A the liquor which is to be distilled, until the level is within 2 or 3 inches of the top of the gauge *x*. The boiler A′ is also charged until the level stands 5 or 6 inches above the cock R′. On opening the stop-cock *r* the tube I, the refrigerator E, and the condenser D, are filled with wine, the air escaping by H′, and as soon as it is seen by the elevation of the level of the liquid in the boiler A′ that wine is flowing over by the tube L, the stop-cock *r* is shut. The fire is then lighted under A, and as soon as the wine in this copper begins to boil, vapour escapes by the pipe Z, condenses in the boiler A′, and by this means, together with the assistance of the heat of the flue which passes under it, the liquor soon boils. The alcoholic vapours ascend in the column B, pass into the worm in D, where they condense, and the liquor returns for the most part into the rectifier C. When the wine in D is sufficiently heated (which is judged of by the outside being too hot for the hand to rest upon it), the stop-cocks R R′ and *r* are opened and the distillation continues. The wine conducted by the pipe I ascends into the refrigerator E, where it is gently heated; it then passes up K into D′, where it is heated still more; and then passing through the opening in the lower part of the diaphragm, it enters D″, where its temperature is raised nearly to the boiling point: it then falls by the tube L into the distillatory column B, where it undergoes considerable subdivision. Having at length reached the boiler A′, it passes through the pipe R′ into the boiler A, and from this it escapes by R, entirely deprived of its alcohol. The vapour from the boilers, which follows the same route, has been already traced.[1]

Thus it will be seen that this apparatus is continuous in its operations; the wine being furnished at one place, and, being deprived of its alcohol, escaping at another in a continued stream. "It is obvious, however, that this still does not literally afford strong alcohol from wine or wash at one distillation, as is commonly said of it; for it actually undergoes repeated distillations in the cylinder. One apparent process only is necessary, and one fire answers for all. In its operations it is continual. There is a saving of fire, superintendence, and time; there is a greater product of alcohol, and the alcohol has a purer flavour, because there are no empyreuma, as the fire is never directly applied to the wine. Indeed, the want of empyreuma has been found an objection to the still: the consumers were so dissatisfied at the want of the accustomed burnt taste, that the required flavour was obliged to be communicated by various empyreumatic substances."[2]

Derosne's apparatus was further simplified by M. Laugier, whose still is described in M. Péclet's work already referred to. We pass on to consider the application of the new stills, or rather of the principles of their construction, to the stills of this country.

The French stills for distilling brandy from wine are not adapted to the glutinous wash of grains, which would soon clog up the small pipes and channels. In introducing the principle of continuous distillation into this country, it was therefore necessary to modify the apparatus. Several such contrivances have been brought forward, among which may be mentioned that by Mr. Æneas Coffey, of Dublin, patented in 1832. It is represented in section in Fig. 720;[3] it consists of a body or oblong vessel, B B′, and two columns erected thereon, one of which, C D E F, is the *analyser*, and the other, G H I K, the *rectifier*. The whole is made of wood, lined with copper, and the wood being 5 or 6 inches thick, little or no heat is

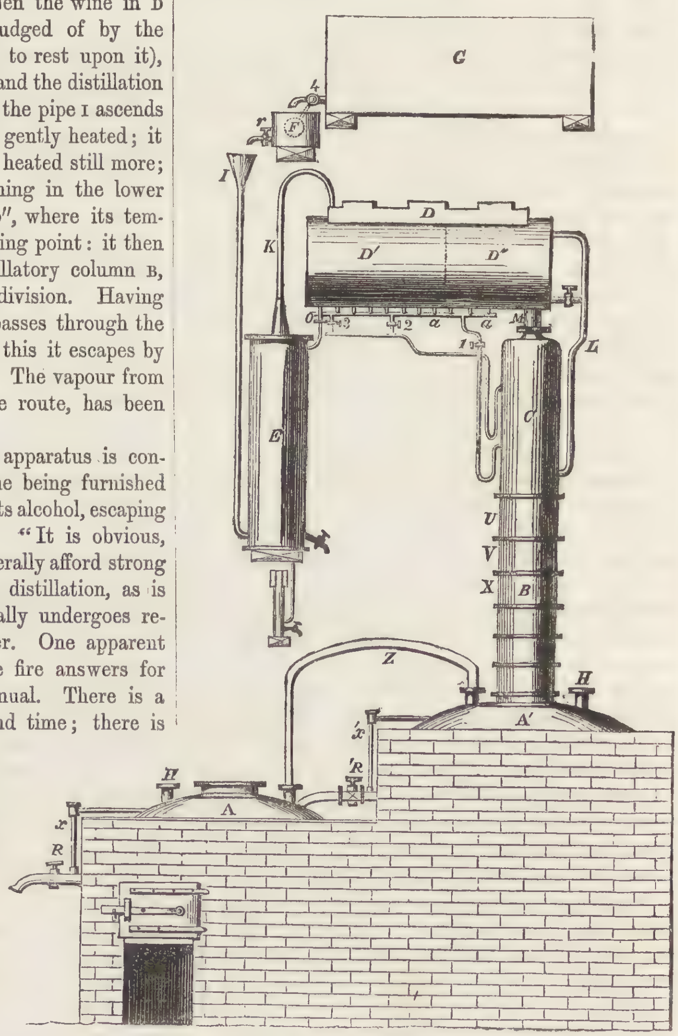


Fig. 718. FRENCH BRANDY STILL.

(1) Péclet: "Traité de la Chaleur, considerée dans ses applications."
(2) Donovan: "Domestic Economy" vol. ii.

(3) We are indebted for this figure and description to Dr. Thomson's "Records of General Science," vol. iii.

lost by radiation. The body has a copper plate or diaphragm, *cd*, across the middle, which divides it into two chambers, B B′. This diaphragm is perforated by a great number of small holes, for the passage of the vapour upwards during the process, and it is also furnished with several valves, which open upwards as shown at *e e*, whenever the vapour is in such quantity as not to find a free passage through the perforations. A pipe, V V, descends from this diaphragm nearly to the bottom of the lower chamber B, into a pan forming a steam-trap, and there is a valve on the top of this pipe which can be opened or shut at pleasure by means of a rod *t*, passing through a stuffing-box on the top of the vessel. Glass tubes at *x x* show at all times the level of the liquor in the chambers B B′.

The analyser C D E F consists of 12 chambers, *f f*, formed by the interposition of 11 copper diaphragms, *g h*, *g h*, &c., all perforated with numerous holes, and furnished with valves opening upwards, as in the large diaphragm *c d*. To each of them is attached a dropping pipe, *h h*, by which the liquor is allowed to flow from plate to plate: the upper end of each of these pipes projects an inch or two above the plate in which it is inserted, so as to retain at all times during the distillation a stratum of wash of that depth on each diaphragm; the lower end of each pipe dips a little way into a shallow pan lying on the diaphragm underneath, forming thus a steam-trap by which the escape of vapour through the pipe is prevented. The pipes are inserted at alternate ends of the diaphragm, as shown in the figure.

The column G H I K is divided in a similar manner into chambers by interposed copper plates or diaphragms. There are 15 chambers in this column; the lowermost 10, *v v*, constitute the rectifier, and its diaphragms are perforated and furnished with valves and dropping pipes, as in the analyser. The uppermost 5 of these frames form the *finished spirit condenser*, and are separated from the other 10 by a copper sheet or diaphragm, not containing the small perforations, but having a large opening at W for the passage of the spirituous vapour, and a dropping pipe at S. There is a neck above the opening W, rising an inch or so above the surface of the diaphragm, which prevents the return of any finished spirit by that opening. Under the dropping pipe S is a pan much deeper than those of the other dropping pipes, and from this pan a branch pipe, *y*, passes out of the apparatus, and carries the condensed, but still very hot spirits, to a worm or other refrigerator, wherein they are cooled. The chambers *v′ v′* of this finished spirit condenser are formed of plain unperforated diaphragms of copper, with alternate openings at the ends, large enough both for the passage of the vapour upwards, and of the condensed spirit downwards; the use of these diaphragms being merely to cause the vapour to pass along the pipes in a zigzag direction, and thus to be more perfectly exposed to their condensing surface. In every chamber, both of the finished spirit condenser and of the rectifier, there is a set of zigzag pipes, placed as shown in the plan, Fig. 719; each set of these pipes is connected with the others by the bends *l l l*, and they thus form one continued pipe, leading from the wash-pump, Q, to the bottom of the rectifier, whence it finally passes out, and rising up, enters the top chamber of the analyser, into which it discharges itself at *n′*.

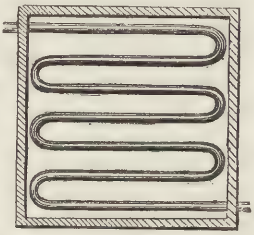


Fig. 719.

M is the wash charger, L a smaller wash vessel connected with it, and with the wash-pump. This vessel is called the *wash reservoir*, its use being to retain a sufficient reserve of wash, to prevent the apparatus being idle during the delay which the Excise regulations render unavoidable, between the emptying of the wash charger and the refilling of it from a new back.

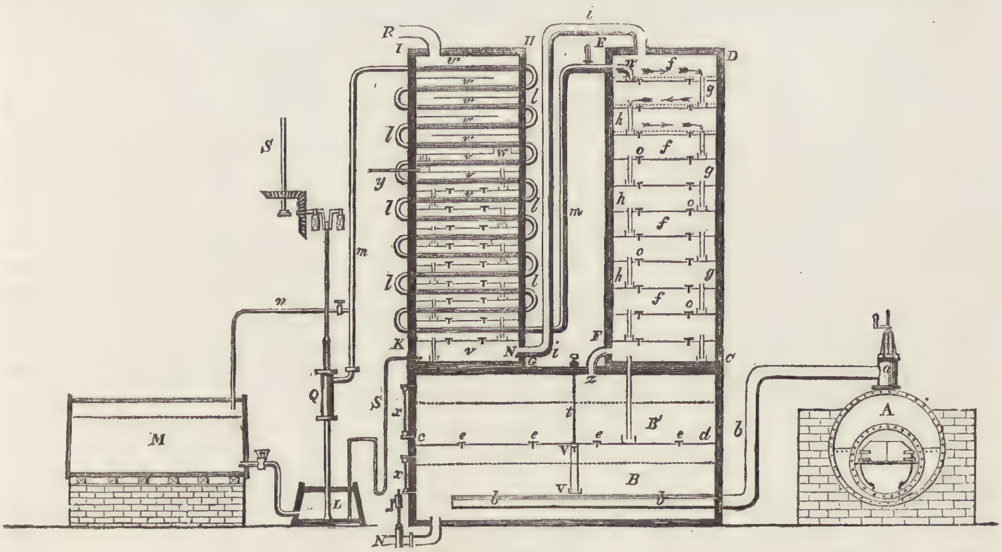


Fig. 720. COFFEY'S STILL.

During the distillation the pump Q is worked continuously, so as to supply the apparatus with a regular stream of wash. It is so constructed as to be capable of furnishing somewhat more than is necessary, and there is a pipe, *n*, with a cock on it, by which part of what is pumped up may be allowed to run back, and thus regulate the supply.

A is a steam boiler, which conveys steam into the bottom of the spent wash receiver by the pipe *b*, which, after entering the receiver, branches into a number of smaller pipes perforated with holes, by which the steam is dispersed through every part of the wash in which they are immersed: these perforated pipes are not shown in the engraving.

The action of this still is as follows:—At the commencement of an operation the wash pump is first set in motion to charge all the zigzag pipes, until the wash passes over into the analysers at *n'*. The pump is then stopped, and the steam let into the bottom of the apparatus by the pipe *b b*. The steam passes up through the chambers B B', and by the pipe *z* into the analysers, from whence it descends through *i i* to the bottom of the rectifier at N. It then rises through the chambers *v v*, enveloping the zigzag pipes, and rapidly heating the wash contained in them. When the attendant finds, by feeling the bends *l l*, that the wash has been heated in several layers of these pipes, (perhaps 8 or 10 layers,) he again sets the pump to work, and the wash, now boiling hot, or nearly so, and always in rapid motion, flows from the pipe *m* at *n'*, and passes down from chamber to chamber through the dropping pipes in the direction shown by the arrows in a few of the upper chambers. No portion of the wash passes through the small holes perforated in the diaphragms which separate the chambers. These holes are regulated, both in number and size, so as to be not more than sufficient to afford passage to the vapour upwards under some pressure. The holes, therefore, afford no outlet for the liquor, which can only find its way down in the zigzag course indicated by the arrows. It is evident, therefore, that the wash as it passes down is spread into strata as many times as there are diaphragms, and is thus exposed to the action of the steam constantly blowing up through it. As it descends from chamber to chamber its alcohol is abstracted by the passage of the steam through it, and by the time the wash has reached the large chamber, B, it is in the ordinary course of the operation completely deprived of its alcohol.

The wash as it descends from the analyser accumulates in the upper large chamber B', until that chamber becomes nearly filled, which when the attendant perceives to be the case by the inspection of the glass tube, he opens the valve of the pipe V, and discharges the contents of B' into B; then shutting the valve, the wash from the analyser again accumulates in B', and when it is a second time nearly full, the contents of the lower chamber B are discharged from the apparatus altogether, through the cock N, and the charge in B' is let down into B by opening the valve as before, and thus the process goes on so long as there is any wash to supply the pump. When all the wash is gone, a quantity of water is let into the reservoir L, and pumped through the pipes, to finish the process and obtain the last portions of alcohol. This winding up of the operation by sending water through the pipes takes place on the distillation of every back of wash, in consequence of an Excise regulation, which requires the distiller to keep the produce of each back separate from any other. Were it not for this regulation, the distillation would go on uninterruptedly, so long as there was any wash in stock; the addition of water for winding up would be necessary but once during the distilling period, and the manufacturer would save much time and fuel, at present wasted by these interruptions.

In the ordinary course of the operation, the wash is deprived of all its alcohol by the time it has reached the bottom of the analyser, but as a precautionary measure the chambers B' B are added, in each of which the spent wash is exposed for about half-an-hour to the action of the steam blowing through it.

There is a small apparatus, not shown in the Figure, by which a portion of the steam in the chamber B' is condensed, cooled, and made to flow constantly through a sample jar in which is a hydrometer, or two glass bubbles, one of the sp. g. 1,000 and the other 998. The attendant knows that all is going on well when these bubbles, or the lighter of the two, float in the sample. In this way the chamber B may be emptied without any risk of loss.

The course of the wash being understood, we will next trace that of the steam, which as it rises is first blown through the charges of spent wash in the chambers B' B: thence it passes up through the layers of wash on the 11 diaphragms of the analyser. In its passage it abstracts from these layers of wash their alcohol, depositing in its place an equivalent quantity of water. After traversing the whole of the analyser, the vapour, now containing much alcohol, passes by the pipe *i i* into the bottom of the rectifier, and as it ascends, it envelopes the pipes, heating the wash and at the same time parting with its more watery portion, which is condensed, and falls, in a boiling state, on the several diaphragms of the rectifier. By the time the vapour reaches the passage W, in the bottom of the finished spirit-condenser, it is nearly pure alcohol, and, as it is condensed by the wash in the pipes, and falls on the diaphragm, it is conveyed away by the pipe *y* to a refrigerator. At the top of the spirit-condenser is a large pipe R, which serves as a vent for the incondensible gas which is disengaged in the process, and this pipe also communicates with the refrigerator, so that, should vapour at any time be sufficiently elastic to pass out of the apparatus, no loss is sustained beyond the waste of fuel caused by condensing that vapour by the water of the refrigerator instead of the wash of the condenser. The liquor condensed on the several diaphragms of the rectifier, after being blown through by the vapour passing up from plate to plate, descends to the bottom in the same manner as the wash descends from chamber to chamber in the analyser: but this condensed liquor still contains a portion of alcohol, and

it is conveyed by the pipe S to the pump Q, by which it is pumped up with the wash to be again distilled. A thermometer near E shows the attendant the temperature of the wash as it issues from the pipe *m* into the analyser, which is the only guide which he requires for managing the operation, for when the proper temperature is maintained the work goes on well: when the thermometer indicates too high a temperature, more wash should be let into the apparatus, and *vice versa;* the quantity being regulated by the cock on the pipe *n*. The difference of a few degrees above or below the proper heat is not, however, of much consequence.

The water for supplying the boiler passes through a long coil of pipe immersed in the boiling hot spent wash, by which means it is raised to a high temperature before it reaches the boiler. The vapour which passes through this apparatus is all condensed by the wash, not by the water; so that no heat is wasted. It is stated that about three-fourths of the fuel used with the common stills is saved by this apparatus. By the common process, to distil a gallon of proof spirits 12lbs. of coal are required, 9lbs. of which are saved by this apparatus. Supposing the whole quantity of spirits distilled in Great Britain and Ireland to be 36,000,000 gallons, and that the improved still is adopted, the saving of fuel would amount to 140,000 tons of coal per annum.

It will be seen from the above description, that Coffey's still, in its principle as well as most of the details, closely resembles the French stills already described. One feature peculiar to the British stills is their enormous size.[1] One of Coffey's stills, at Inverkeithing, distils 2,000 gallons of wash per hour, and there is one at Leith which distils upwards of 3,000 gallons per hour. Some of the store vats also rival those of the London porter brewers. 20,000 gallons of whiskey are sometimes stored in one vat.

Dr. George Wilson has kindly furnished the Editor with the following information respecting the stills used in the Scotch distilleries.

He says:—"Three kinds of still are in use in Scotland; 1. *Coffey's*, which is everywhere supplanting all others for the preparation of *grain* whiskey; 2. *Stein's*, which is the same in principle as Coffey's, and is used to a considerable extent in the preparation of *malt*-whiskey; 3. The old simple still, which continues to be largely employed, but only for malt-whiskey, and this is usually distilled twice. Coffey's still derives so large a per-centage of alcohol from the wash, that the old trade of rectifying spirit has ceased in this quarter, and the strongest commercial spirits of wine are made by a single operation. At Sunbury, they distil water as well as alcohol, and the latter is reduced to a drinkable strength by a suitable dilution supplied by the former. Coffey's still produces the strongest spirit, and takes no heed of flavour. Whiskey drinkers, however, do not love what chemists call the pure hydrated oxide of ethyle, and thus it happens, that less potent stills than Coffey's are employed to imbue the spirit with aroma. The still at Sunbury produces alcohol at 64 or 67 over proof. In an apparatus which is supposed to combine the advantages of Coffey's and Stein's, spirit is produced 16 or 20 over proof.

"The product of the Coffey still requires only dilution to be at once marketable. Most of the Scotch whiskey sold in England is manufactured by this still. It is characterised by the absence of any marked flavour, except in a very faint degree, in consequence of the method of distillation preventing the less volatile fusel oil, and other strong scented products of fermentation, from passing over with the spirit. Malt-whiskey (made from malted grain) contains those flavouring ingredients which certain connoisseurs prefer: the *small-still* whiskey of the Scotch smuggler, and the *potheen*, (the Irish equivalent of small-still, or *little pot,)* being prized for their *peat-reek*, or *turf-smoke* flavour. In the manufacture of these malt whiskeys, in which potatoes and treacle or sugar are sometimes used, and sometimes raw grain, but this only to a small extent, the old-fashioned simple still, endlessly varied but generally with a high head, is employed. Two-thirds or more of what is called *malt whiskey*, and sold as such, is grain whiskey flavoured with a dose of the most odorous malt spirit."

The manufacture of spirits is a fruitful source of revenue, and is closely watched over by the officers of excise. Their duties in this particular, as well as those of the distillers, are contained in a long and complicated act of parliament, with which it behoves them to be well acquainted, for there are penalties for the infringement of the various clauses amounting to many thousand pounds. The following is an abstract of Macculloch's account of these duties, which we preface with his own sensible remarks:—"There are perhaps no better subjects for taxation than spirituous and fermented liquors. They are essentially luxuries; and while moderate duties on them are, in consequence of their being generally used, exceedingly productive, the increase of price which they occasion has a tendency to lessen their consumption by the poor, to whom, when taken in excess, they are exceedingly pernicious. Few governments have been satisfied, however, with imposing moderate duties on spirits; but partly in the view of increasing their revenue, and partly in the view of placing them beyond the reach of the lower classes, have almost invariably loaded them with such oppressively high duties, as have entirely defeated both objects. The imposition of such duties does not take away the appetite for spirits; and as no vigilance of the officers or severity of the laws has been found sufficient to secure a monopoly of the market to the legal distillers, the real effect of the high duties has been to throw the supply of a large proportion of the demand into the hands of the illicit distiller, and to superadd the atrocities of the smuggler to the idleness and dissipation of the drunkard.'

(1) Messrs. Wylie & Co. of Glasgow have sent us a drawing and description of Mr. Maxwell Miller's patent distilling and rectifying apparatus, which we have not been able to insert for want of space.

The prevalence and direful effects of gin-drinking in the latter part of the reign of George I., and the commencement of the succeeding reign, were so marked, that public attention was strongly drawn thereto. It was naturally thought that the cheapness of spirits, and the great number of public-houses, were the sources of this general evil; and, forgetful of the danger of extreme measures, the ministry of the period (1736) passed a stringent act, which prohibited altogether the use of spirituous liquors, except as a cordial or medicine. This attempt, not to regulate and repress the drinking of gin, but to abolish it altogether, was most unwisely made, and had an effect directly opposite to what was intended. The enormous duty of twenty shillings per gallon was laid on spirits, besides a heavy licence duty on retailers, and every encouragement was given to informers to seek out those who should vend the smallest quantity of spirits which had not paid the full duty, and to exact the penalty of 100*l.* for the offence. On the passing of this act, respectable dealers withdrew from the trade, and it fell chiefly into the hands of low and profligate characters, who, having nothing to lose, were not withheld by penalties from breaking through its provisions. The populace supported the cause of the smugglers and unlicensed dealers; informers were hunted down like wild beasts, drunkenness and crime rapidly increased, and in two years the act had become so contemptible, and was so openly set at nought, that policy as well as humanity forced the commissioners of excise to mitigate its penalties. Within those two years 12,000 persons were convicted of offences connected with the sale of spirits, and, in spite of all prohibitions, 7,000,000 gallons were annually consumed in London and its vicinity alone. Under such circumstances, government soon gave up the unequal struggle, the high duties were repealed, and moderate ones imposed in their room. The consequences were highly beneficial: an immediate stop was put to smuggling, and to the serious crimes and disorders connected with it, while gin-drinking, to say the least, was not increased by the change.

It has been too long the policy with respect to Ireland to exact heavy duties on spirits; and in consequence smuggling has been carried on to a great extent in that country. An Irish whiskey-still has been chosen by artists as a subject characteristic of the people, and at one time the attempts to put down illicit distillation met with so determined a resistance that the country was filled with anarchy and bloodshed. Any one found working an unlicensed still was subjected to transportation for seven years, and a heavy fine was imposed on the parish or manor where the still was found. This was intended to engage proprietors heartily in the work of putting down the practice. In 1822, when the duty on spirits was 5*s.* 6*d.* per gallon, the annual consumption of spirits in Ireland was estimated at 10,000,000 gallons, while scarcely 3,000,000 paid duty, so that 7,000,000 must have been illegally supplied. This vast amount of smuggling was carried on in the teeth of the above heavy penalties, and in despite of the utmost exertion of the military and police to prevent it. To put an end to such evils the duties were in 1823 reduced from 5*s.* 6*d.* to 2*s.* 4*d.* (imperial gallon), and with the most satisfactory results. The consumption of spirits was not increased thereby, but a considerable increase to the revenue resulted from the substitution of legal for illegal distillation, while the evils of smuggling became nearly extinct. An extraordinary decrease in the consumption of spirits in Ireland took place in 1839, which is chiefly to be ascribed to the great exertions made at that time in the Temperance cause.

The history of the spirit trade in Scotland corresponds in a great measure with that of Ireland. While the duties were high, the quantity of illegally distilled spirits annually produced in the Highlands amounted to about 2,000,000 gallons. In corroboration of this it is stated, that in 1821 only 298,138 gallons were brought to the charge in the Highlands, and of these 254,000 gallons were permitted to the Lowlands, leaving only 44,000 gallons for the consumption of the whole of the Highlands, a supply which would hardly be sufficient for the demand of two moderately populous parishes. During this state of things the natural results exhibited in various districts were thus alluded to in a letter from Captain Munro, of Teaninich, to the Commissioners:—"The moral effects of this baneful trade of smuggling on the lower classes are most conspicuous, and increasing in an alarming degree, as evidenced by the multiplicity of crimes, and by a degree of insubordination formerly little known in this part of the country. In several districts, such as Strathconon, Strathcarron, &c., the excise officers are now often deforced, and dare not attempt to do their duty; and smuggled whiskey is often carried to market by smugglers escorted by armed men, in defiance of the laws. In short, the Irish system is making progress in the Highlands of Scotland." The remedy in this case, as in the other, was the reduction of the duty. It was lowered in 1823 from 6*s.* 2*d.* to 2*s.* 4¾*d.*, and in 1830 was slightly raised to 2*s.* 10*d.*, 3*s.*, and 3*s.* 4*d.* The influence of the reduction in 1823 was to double the consumption of duty-paid spirits, while at the same time illicit distillation was all but suppressed.

Before the Irish and Scotch duties were lowered, the duty on English spirits had been as high as 11*s.* 8*d.* per gallon. This high duty and the restrictions under which the trade was placed were productive of the worst effects. They went far to enable the distillers to fix the price of spirits, and consequently to raise it much beyond that which was sufficient to repay, with a profit, the cost of the manufacture and the duty. The commissioners found in 1823, that "when corn spirits might be purchased in Scotland for about 2*s.* 3*d.* a gallon, raw spirits could not be purchased in England for less than 4*s.* 6*d.* ready money, and 4*s.* 9*d.* credit, omitting, in both cases, the duty." In consequence, smuggling was carried on to a great extent in England; and the large profits made by the smugglers caused clan-

destine importations from Scotland and Ireland. To obviate these inconveniences, and at the same time to neutralize the powerful additional stimulus that the reduction of duties in Scotland and Ireland would have given to smuggling, had the duties in England been continued at their former amount, the latter were reduced in 1826 to 7*s.* a gallon, facilities being at the same time given for the importation of spirits from other parts of the empire. There was a great objection made to this, on the ground that it would increase drunkenness, but these fears have proved groundless. The consumption of British spirits in England and Wales in 1823 was estimated at 5,000,000 gallons; and it appears that in 1844 it amounted to 7,719,459 gallons, producing 3,023,445*l.* of revenue. Now, making allowance for the increase of population, and for the check given to adulteration and smuggling, and considering also that the consumption of foreign spirits was not greater in 1843 than in 1823, it is fairly estimated that the practice of spirit-drinking, although acknowledged to be far too prevalent, has not increased within the last twenty years. All these instances sufficiently prove that any attempt to check the excessive practice of spirit drinking in a country by imposing heavy duties and restrictions, is so far from having the desired effect, that it actually promotes the consumption of spirits, and leads to a whole catalogue of evils in the shape of adulteration, smuggling, vexatious informations, tumult, and rebellion against constituted authorities.

The following table shows the total number of proof gallons of spirits distilled in the United Kingdom:—

Year.	England.	Scotland.	Ireland.	Total.
1845	5,567,366	9,193,006	8,216,794	22,977,166
1846	5,634,466	9,559,611	8,333,240	23,527,317
1847	5,479,162	8,613,753	5,988,053	20,080,968
1848	5,717,247	9,618,299	7,995,188	23,330,734
1849	5,318,526	10,444,709	8,117,844	23,881,079

The amount of duty paid on home consumption was for the year ended Jan. 5, 1850, in England, 3,546,023*l.*; in Scotland, 1,271,417*l.*; in Ireland, 29,777*l.* The duty is 7*s.* 10*d.* per gallon in England, 3*s.* 8*d.* in Scotland, and 2*s.* 8*d.* in Ireland. The higher duty has to be paid on the transfer to any place where the duty is higher than in the place of manufacture.[1]

In the year ending Jan. 5, 1851, the amount of proof spirits retained for home consumption in the United Kingdom amounted to 23,862,585 gallons; the duty paid amounted to 5,948,467*l.* 19*s.* The import trade in spirits is considerable. In the year ending Jan. 5, 1849, the number of proof gallons of rum imported amounted to 5,306,827 gallons; of brandy, 4,479,549 gallons; of Geneva, 471,232 gallons. The total amount of foreign, colonial, and Channel Island spirits imported in that year amounted to 10,509,774 gallons, of which 5,284,975 were retained for home consumption, 3,465,004 exported, 325,235 shipped as stores, and 341,758 delivered for the use of the navy.

(1) Companion to the Almanac, 1851.

DIVIDING ENGINE. See Graduation.

DIVING BELL. We have seen in our article Aerostation with how little success man has endeavoured to extend his dominion to the regions of the air. We have now to trace the history of his more successful attempts to explore the depths of the sea or of rivers, for the purpose of collecting such valuable articles as pearls, sponges, coral, &c., of recovering articles lost by shipwreck, laying submarine foundations, and mining or exploding the rocks which obstruct the entrance of harbours, &c.

The early history of the art of diving, like the early histories of most of the useful arts, contains many wonderful narrations, evidently as much the result of the imagination as of the scientific observation of the narrators. These we pass over in silence. The necessity for a regular supply of atmospheric air reduces the powers of the unassisted diver to very narrow limits; for with the greatest known capacity of lungs, and the strongest inspiration, there is no authentic case of a man being able under ordinary circumstances to take in a supply of air sufficient to maintain him under water for two minutes. In ordinary cases, a sense of suffocation is experienced after the submersion in water of half a minute. Dr. Halley relates the case from his own observation of a Florida Indian diver at Bermuda, who could remain under water for two minutes; but this is doubtless an extreme case. Admiral Hood tested the much-vaunted powers of the Indian divers, with a watch in his hand, and found th[illegible] no case could any one of them remain submerged more than a minute. Halley relates that those who dive in the Archipelago for sponges take into their mouths a piece of sponge, dipped in oil, with the view, as he supposed, of inhaling the air contained in the sponge: the real reason, however, appears to be for the purpose of calming the small waves on the surface which prevent the light from being transmitted to the bottom: by ejecting a little oil from their mouths, it rises to the surface, and spreading upon it, produces smooth water, and gives a steady light at the bottom, which is necessary to assist the divers in finding the small objects they are in search of. It is exceedingly difficult to hold the breath under water, on account of the great fluid pressure on the chest, which increases with the depth. Most divers, by continuing to dive for any length of time in deep water, have blood-shot eyes and a spitting of blood, arising from the great exertion. Many of the natives of the South Sea Islands are such expert divers that if a nail or a piece of iron be thrown overboard, they will jump into the sea after it and recover it.

Attempts have been made at various times by ingenious men to contrive some form of dress, such as would enable the diver to remain under water for an indefinite length of time, his respiration being carried on by means of flexible tubes, communicating with the air above; fresh air being forced down one pipe by bellows or other means, and allowed to return by the other. To prevent the great pressure of the water on the chest of the diver, a sort of water

armour, made tight by leather, was contrived. This answered tolerably well in depths not exceeding twelve or fifteen feet. At greater depths, it was necessary to the free motion of the diver to have his limbs exposed; and the pressure on them was found to be so great as to obstruct the circulation of the blood, while those parts of the body encased by the armour being relieved from pressure, the blood was forced from the limbs into them, thus producing much suffering. One of the best forms of armour was Klingert's, which has often been described. In other forms of apparatus, the diver was completely shut up in a vessel, and moved about by means of tackle connected with the ship above. Submarine boats have also been proposed at different times, for the purpose of destroying an enemy's shipping. These have not been very successful; and we trust the time will not again arrive when such inventions will be, if under any circumstances they can be, desirable.

All these contrivances have been for the most part superseded by that simple and beautiful machine, the diving bell, which has already been of such vast service in subaqueous operations. By its means, too, three or more men can descend in company, move about with perfect freedom, and employ tools for accomplishing the intended object at the bottom of the sea; they can also descend to a greater depth than by any other contrivance, and continue a very much longer time below, and, if necessary, they can carry a light down with them for the purpose of guiding their works.

Several allusions are made to diving machines, more or less resembling the diving bell, previous to the time of Dr. Halley, who has the merit of, at least, rendering former attempts practicable. Halley's bell was of wood, of the internal capacity of about sixty cubic feet; its form a truncated cone, the diameter at top being three feet, and at bottom five. It was covered with lead, so that it could sink empty, and the weight was so distributed at the bottom that it would go down perpendicularly. Light was admitted at the top through a strong clear glass, and the hot vitiated air was let out through a cock at the top. About a yard below the bell was a stage suspended by three ropes, each loaded with about a hundredweight. The bell was suspended from the mast of a ship, carried overboard clear of the ship's side. Air was supplied to the bell by means of a couple of barrels of about 36 gallons each, cased with lead so as to sink when full of air: the bung-hole at the lowest part was left open, so that a portion of water entered the casks, and condensed the air during their descent: a leathern hose was attached to the top of each cask, the open end of which hung down by a weight below the bung-hole, so that the air could not escape unless this open end were raised. These two buckets were fitted with tackle, and made to ascend and descend alternately like two buckets in a well. The hose of the descending barrel being taken up into the bell, the water would rush into the cask, drive out the air before it through the hose into the bell, and the cask being thus filled with water, was drawn up, when the water flowing out, its place was supplied with air; while in the meantime the other cask would in its turn be discharging its contents into the bell. In this way, Dr. Halley states that he, with four others, have continued in the bell, in 9 or 10 fathoms water, for an hour and a half, without inconvenience. "The whole cavity of the bell was kept entirely free from water, so that I sat on a bench which was diametrically placed near the bottom, with all my clothes on. I only observed that it was necessary to be let down gradually at first, as about twelve feet at a time, and then to stop and drive out the water that entered, by receiving three or four barrels of fresh air before I descended further; but being arrived at the depth designed, I then let out as much of the hot air that had been breathed as each barrel would replenish with cool, by means of the cock at the top of the bell, through whose aperture, though very small, the air would rush with so great violence as to make the surface of the sea boil, and to cover it with a white foam, notwithstanding the great weight of water over us."

In 1721, Dr. Halley invented additional apparatus to enable the diver to go out from the bell to some distance, and remain a sufficient time in the sea. The man was supplied with air by a bell or cap of lead with glass eyelets, which completely covered his head, and was supplied with air from the bell by means of a flexible tube. To diminish his buoyancy at this depth, weights of lead were attached to his girdle and clogs of lead to the feet.

Improvements or variations were made in Dr. Halley's bell by Mr. Martin Triewald, and by Mr. Spalding. Some of these were ingenious and were admired at the time; but the simple form of bell which is now in use seems to be preferred to the more complicated machines. To Smeaton belongs the merit of applying the diving bell to the operations of engineering, to which it has since rendered such essential service. About the year 1779, Smeaton used it in repairing the foundations of the piers of Hexham Bridge, which had been undermined by the violence of the current sweeping away the gravel from under the floor timbers of the caisson in which they were founded. In this way he succeeded in underpinning the foundations of some of the piers. The accident which followed in 1782, when the whole structure was carried away by a sudden and violent flood, only proved the insufficiency of the natural bed of the river. [See Bridge, Fig. 294.]

To Smeaton also belongs the merit of inventing the modern form of bell, consisting of cast-iron. The first bell of this kind was made about 1788, for carrying on the works at Ramsgate harbour. This bell weighed 50 cwt.; it was heavy enough to sink itself without the addition of external weights: its height was $4\frac{1}{2}$ feet, its length the same, and its width 3 feet, thus affording space for two men to work under it at a time.[1] It was also peculiar to this machine that the men were furnished with a constant supply of fresh air without any attention on their part, by means of a forcing air-pump contained in the boat

(1) A larger bell, 6 feet long and 4 broad, was subsequently used.

above. The bottom part of this bell B B′, Fig. 722, was made very thick to give it sufficient weight, and in the crown, Fig. 721, were 8 round holes, each furnished with a lens 4 inches diameter, fitted into a brass cell and then screwed into the cast-iron. In the centre was a hole *h*, to receive a brass screw at the end of the leather pipe for introducing the air. This hole on the under side had a leather valve stretched over it to prevent the return of the air, and also a grating of iron across it to support the valve against the pressure when it was shut. The valve was a square piece of leather stretched over the hole and fixed to the iron by a screw at each corner, not so tight as to prevent it from opening to admit the air: *e e* are two strong eyes to receive the chains which suspend the bell, and there are similar eyes within the crown, to suspend an iron link L, to which chains may be attached. The whole is cast in one piece: *s s′* are two seats for the divers to sit upon as they descend; but these turn up upon hinges when they are at work.

The pier which was afterwards built upon the foundation cleared by this diving bell, was founded by caissons, [See BRIDGE;] but not being done very substantially or with large stones, the work had become so bad as to require renewal in some places, and in others to be defended by an apron or outside wall of very solid masonry, which was laid by means of the diving bell. The machinery employed is shown in elevation, Fig. 723, and the following description of its use applies to the method introduced by Smeaton. The cast-iron bell is seen in section attached by two chains to the three-sheaved block *b*; another block *b′*, with three sheaves is supported between two long timbers T T′. These are united to form one frame, and to strengthen them, king-posts K, and riders R R′, are erected upon them, and very strongly tied by iron straps and wooden knees. These beams traverse upon a centre pin *p*, which is fixed into a very heavy stone; and they are also supported by small wheels which run upon a railroad I, which is curved to a segment of a circle. The extremity T′ of the frame has a heavy stone attached to it, to balance the weight of the bell appended from the opposite end. The fall of the tackle is conducted through a block *x*, to a capstan by which it is taken up or let down. This machine is placed upon the top of the pier wall W, at the foot of which, the stones shown as dotted are to be laid by the divers. In order to move the bell nearer to or further from the wall, the block *b′* is moved in the beams: to haul it in, a pair of blocks *e f* are used, and it is drawn out by a rope passing through a block at T, and then to another pair of blocks not shown in the figure; to move it sideways, two pair of tackles are applied, one pair shown at *l m*, and another pair on the other side not shown. P is the leathern pipe conducted from the bell to the forcing pump N, fixed on board the boat, and is worked by the lever *n*; *r* is a rope extended from the bell to the boat, and being shorter than the pipe, it prevents it from being broken or stretched by the wind or tide carrying the boat away; and it is also secured to the pier by the rope *r*. The man at the pump N forces down so much air to the bell as will cause the air to flow out beneath the lower edge of the bell and rise in bubbles to the surface: as long as this continues he knows that the divers are well supplied with air. Signals are given by the bellman with a hammer struck on the inside of the bell: thus, 1 blow signifies "More air;" 2 blows, "Stand fast;" 3, "Heave up;" 4, "Lower down;" 5, "To eastward;" 6, "To westward;" 7, "From the wall." The stones are all prepared and jointed together with dovetails before they begin to lay them; and the first thing to be done is to make the foundation perfectly level and true. The loose sand &c., is removed by dredging from above in the usual manner, and then the bell with two men in it is let down to the bottom, which at Ramsgate is a hard chalk rock: when it stands thereon, it lays the chalk dry to the level of the bottom edge of the bell; but if the surface is uneven, the bell cannot descend so low but that it will leave 6 or 8 inches of water on the bottom. The surface of this water is the level they work to, and by cutting away every eminence which rises above the water they soon obtain a perfectly level surface. They work with a small pick, made something like a narrow adze, and as the chalk is not hard, the work proceeds rapidly. When they have accumulated a certain quantity of rubbish, they knock three times on the bell, to order the people to draw it up, till they, standing on the bottom, find themselves knee deep, then two knocks to stand fast. They now take in a shallow basket let down from above, and fill the rubbish into it, then pull the rope to order it to be drawn up, and strike four times on the bell that they may be lowered down to proceed with their work. Having in this way hewed away the surface till the water standing equally all over it shows it to be a level plane, they give orders to be removed to a new situation, yet at so small a distance that part of the surface just levelled is still beneath the bell: in this way a uniform plane is preserved, and the rock is prepared for the stone work without any other level than the water. The stones are hoisted by a crane, moving on wheels so that it can be wheeled upon the pier to the required spot close to the diving machine. The first stone is taken up by it out of the boat, the hooks of the crane rope being put in the ring of a lewis; the stone is turned round into the position in which it is to be laid, and lowered to the bottom as close as is convenient to the bell; then by shaking the crane rope, its hook is disengaged from the ring of the lewis, and without moving the crane the rope is drawn up. The bell is then drawn up 2 or 3 feet, and by the various tackles it is moved to such a position that the centre of the upper block comes exactly under the hook of the crane rope: this like a plumb-line shows that the bell is brought exactly over the stone. The bell is now lowered down upon it, and the divers reeve a strong chain through the ring of the lewis, and also through a ring or iron loop, L, Fig. 722, in the top of the bell. On heaving up, the stone with the bell

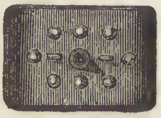


Fig. 721.

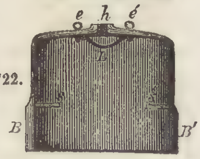


Fig. 722.

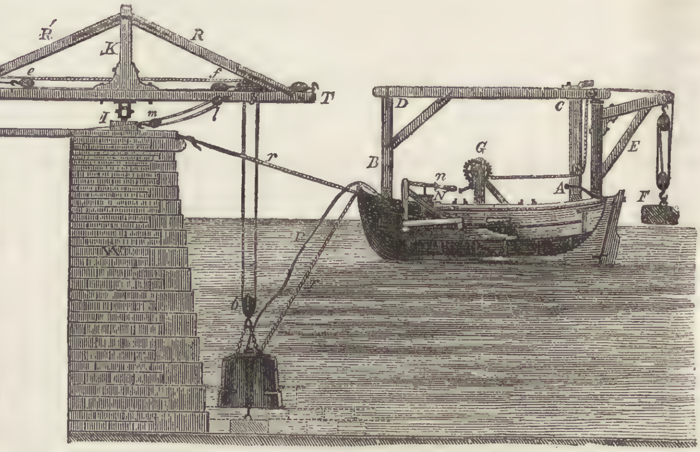


Fig. 723. SMEATON'S ARRANGEMENT FOR CARRYING ON THE WORKS AT RAMSGATE HARBOUR.

is lifted off the ground, and the men direct by signals how it is to be moved in order to convey it to the destined spot; which being carefully done, they proceed with the bell to take up a second stone, which had in the meantime been lowered to the bottom by the crane. No cement is used to unite these stones, as they are all dovetailed into each other, and the joints are then wedged quite fast by oak wedges driven down, and lastly by sand rammed very hard into all the interstices between the dovetails. The great weight of the stones defends them from the action of the sea, every one of the lower course being 3 feet wide by $4\frac{1}{2}$ long, and 2 feet 3 inches thick. Notwithstanding their great weight, the tackle for the bell is so well made as to lift the stone with the bell altogether, and move it with great precision. The crane boat used for building the pier, when it comes above water, as well as for assisting the operations of the diving bell, is also shown of a reduced size in the figure. It is a strong boat of 30 or 40 tons burthen, with a frame ABCD, erected upon it to support the crane gibbet E, from which the stone F is suspended by the rope and raised by the windlass G with cog-wheels.[1]

Since the completion of Ramsgate Harbour, the diving bell has been applied by Mr. Rennie and other engineers with great success to a variety of similar operations in Dublin, Donaghadee, and other harbours in Ireland, at Holyhead and Portpatrick on this side of the channel, and in other parts of the kingdom. The diving bell has also been used in bridge-building, and in the repairs of bridges. In the construction of the Lary Bridge, near Plymouth, Mr. Rendel caused the pile heads to be levelled and the spaces between them paved by means of a diving bell.[2] The work was executed with safety and expedition, and Mr. Rendel expresses his conviction that diving bells may be employed by the bridge-builder in a variety of cases with much greater advantage and economy than coffer dams.

The common rectangular diving bell is subject to considerable vibration in rapid streams. It has been proposed by Col. Pasley and others to attach boat-shaped ends to it: on descending in a bell thus provided at the half ebb of a strong flood tide, the Colonel found it perfectly steady.

It is not often that a competent observer will condescend to publish his observations of phenomena which are supposed from their daily occurrence to be perfectly well known. There are, however, numerous facts of great and permanent interest connected with the diving bell, which can only be accurately observed and faithfully recorded by a scientific man. Such a narrative has been given by Dr. Colladon of Geneva, the results of whose experience were given in a paper read before the Royal Society of Edinburgh in April, 1821; from which we gather the following particulars. Dr. Colladon, being in Ireland in September, 1820, had an opportunity of going down in a diving bell then in use at Howth Harbour, near Dublin. The weather at the time was very fine, but the wind rather high, and the sea rough. The party got into a boat at 11 o'clock, A.M., and in a few minutes came alongside a vessel to which the diving bell was attached. The workmen were then at the bottom of the water, employed in clearing the entrance of the harbour. The bell was a kind of oblong iron chest, cast in one single piece, open below, 6 feet long, 4 broad, and 5 high: it weighed 4 tons, it was 3 inches thick at bottom, and half that thickness at top. It was cast in London, and, including the necessary apparatus and the air pump, cost about 200*l*. The bell being a great deal heavier than the water which it displaced, descended by its own weight. The upper part was pierced with 8 or 10 holes, in which were fixed the

(1) "Historical Report on Ramsgate Harbour, wrote by order of and addressed to the Trustees by John Smeaton, C.E. F.R.S. and engineer to Ramsgate Harbour, 1791." Smeaton's Reports, vol. iii. Also Edinburgh Cyclopædia: article, *Diving Bell*.

(2) This diving bell was constructed on the spot for the purpose: it was made of wood in two thicknesses, and the joints were made tight by means of slips of flannel saturated with bees'-wax; the inner case was also covered within and without with flannel similarly saturated. Its weight when finished was $1\frac{1}{2}$ ton, and it required from 5 to $6\frac{1}{2}$ tons to sink it in about 25 feet of water. See "Transactions of the Institution of Civil Engineers." Vol. I. London: 4to. 1836.

Drawn by

Engraved by

same number of thick convex glasses, which transmitted the light. The glasses or lenses were fixed in the top of the bell by means of a copper ring screwed up against the glass, between which and the bell a coat of putty was laid, and then screwed up hard, so as to render it air-tight. The top was pierced with another hole, about an inch in diameter, for receiving a long flexible leather pipe, intended to introduce into the bell the air compressed from above by a forcing-pump. In the inside of the bell was a valve, which served to close the aperture, and prevent the air from escaping. In the interior were two small benches on opposite sides of the bell, with a foot-board between them. There was room enough for 4 persons. From the middle of the roof descended several strong chains, intended to sustain a kind of iron basket, in which were placed the stones or other matters to be carried up. The bell was suspended by the centre with strong ropes, and managed by means of a movable crane, erected on the deck of a small vessel. The party, consisting of Dr. Colladon, a friend, and two workmen, got into the bell, which was sufficiently elevated above the surface for that purpose, by means of a boat placed underneath it. They descended so slowly that they did not notice the motion of the bell; but as soon as the bell was immersed in water, they felt about the ears and the forehead a sense of pressure which continued increasing during some minutes:—

"I did not, however, experience any pain in the ears; but my companion suffered so much, that we were obliged to stop our descent for a short time. To remedy that inconvenience, the workmen instructed us, after having closed our nostrils and mouth, to endeavour to swallow and to restrain our respiration for some moments, in order that, by this exertion, the internal air might act on the Eustachian tube. My companion, however, having tried it, found himself very little relieved by this remedy. After some minutes we resumed our descent. My friend suffered considerably: he was pale, his lips were totally discoloured, his appearance was that of a man on the point of fainting; he was in involuntary low spirits, owing, perhaps, to the violence of the pain, added to that kind of apprehension which our situation unavoidably inspired. This appeared to me the more remarkable, as my case was totally the reverse. I was in a state of excitement resembling the effect of some spirituous liquor. I suffered no pain, I experienced only a strong pressure round my head, as if an iron circle had been bound about it; I spoke with the workmen, and had some difficulty in hearing them. This difficulty of hearing arose to such a height, that during 3 or 4 minutes I could not hear them speak. I could not, indeed, hear myself speak, though I spoke as loudly as possible; nor did even the great noise caused by the violence of the current against the sides of the bell reach my ears. After some moments we arrived at the bottom of the water, where every unpleasant sensation almost entirely left us. We were then 27 feet below the surface. I confess that the recollection of the great depth, joined to the idea that if the smallest stone, or other matter, should obstruct the action of the valve, the bell would be instantly filled with water, did not fail to create for a short time a kind of uneasiness. One of the workmen, however, to whom I imparted my thoughts on that subject, desired me, with a smile, to look at one of the glasses placed above us, which I observed to be so much cracked in the middle, that bubbles of air were continually escaping. We breathed during the whole of our stay under water with much ease. We experienced now and then a great heat. Our perspiration was sometimes copious, and sometimes there suddenly came over us so thick a vapour as to prevent my seeing the workmen placed opposite me; but as, by means of the signals, they constantly sent us from above pure air in so large quantities that a great part of what was contained in the bell made its escape with great violence, this inconvenience very soon disappeared. Our pulse was not affected."

Mr. Bald, who went down two days before in another part of the harbour, took with him a thermometer, and found the temperature of the air at the surface and in the inside of the bell to be 63° Fahr., whilst the temperature of the water within a foot of the bottom (that is to say, 19 feet below the surface,) was 56° Fahr. "The light which we had in going down and at the bottom of the sea was very strong. Mr. Bald could distinguish very easily in descending a great number of fishes, and other marine animals, which fled at the approach of the diving bell. The sun shone bright, and I could write and read very easily. We gathered some fuci. We took some marine animals, and obtained several pieces of rock. That part of the bottom of the sea which did not present any rock, was composed of sand and pebbles. The current of water was very violent; the colour of the water, as seen through the glasses, seemed to us to be of a light green; in the bell, where we had about 10 or 12 inches of it, it was quite colourless. Having remained more than an hour at the bottom, and having seen the men work as easily as in the open air, they made some signals, and we ascended, fully satisfied with what we had seen, and convinced of the facility and safety of these submarine operations. Before we went down they had lost their basket at the bottom of the water, and in order to find it again, they were obliged, in using their signals, to have the bell moved in every direction, which gave us the advantage of becoming well acquainted with the method they employed in making themselves understoood. In going up the sensations which we experienced in the head were very different from those which we felt in descending. It seemed to us that our heads were growing larger, and that all the bones were about to separate. This disagreeable sensation, however, did not last long; we were in a short time above the surface, not only much pleased with what we had seen, but also with the idea of emerging safe from our narrow prison."

The signals made use of by the workmen are very simple; they consist in a smaller or greater number of strokes given with a hammer against the sides of the bell. They are easily heard on board, though no

noise made above reaches the bell below. There is north and south end fixed to each bell, and which is always attended to by those on board, so that they can be moved with accuracy whenever they want to work, either south, north, west, or east. The signals for the various operations are as follow:—1 stroke means, "More air," or "pump strong;" 2, "Stand fast," which is applicable to all motions; 3, "Hoist;" 4, "Lower;" 5, "More south;" 6, "North;" 7, "Front;" 8, "Back;" 9, "Lower down the bucket;" 10, "Hoist up the bucket loaded;" and so on. The men also send up a note of what they want upon a label, which is instantly attended to if practicable, or some intimation sent down to them that it cannot be done. This is effected by means of a cord, one end of which is in the bell, and the other upon deck. It is by the signals above described that the bell is moved from one place to another in search of stones. This is effected by raising the bell a few feet from the bottom, and then, by the aid of the moorings of the ship, the bell sweeps along in any desired direction; as soon as a large stone is discovered a signal is made, the horizontal movement is stopped, and the bell lowered over the stone. If the bell be a little aside the workmen can, by standing in the bottom of the sea, and pressing with their shoulders against the bell, make it swing a foot or two in any direction, as it is suspended from an outrigger at some height from the vessel's deck. The men at Howth are principally occupied in clearing the entrance to the harbour. They are paid by the ton weight for what they quarry, and send up, viz.—6*s.* 6*d.* per ton for very hard rock, that has chiefly to be blasted with gunpowder; 5*s.* 5*d.* per ton for easier quarried rock; and 4*s.* per ton for detached stone, gravel, and mud. At this rate they are able to earn on an average 20*s.* per week all the year round. Their tonnage of rock averages 3½ tons per day, and detached stone 5½ tons for 4 men. This method of blowing up rocks by aid of the diving bell, as practised in Ireland, is as follows:—Three men are employed in the bell: one holds the jumper or boring iron, the other two strike alternately quick smart strokes with hammers. When the hole is bored of the requisite depth, a tin cartridge filled with gunpowder about 2 inches diameter, and a foot in length is inserted, and sand placed above it. To the top of the cartridge a tin pipe is soldered, having a brass screw at the upper end. The diving bell is then raised up slowly, and additional tin pipes with brass screws are attached, till the pipes are about 2 feet above the surface of the water. In the old practice the tube was filled with powder in a train, and fired; but in many instances the heat melted the solder of the pipe, and the water entering extinguished the fire. The improved method is to leave the tube empty. The man who is to fire the charge is placed in a boat close to the tube, and to the top of the tube a piece of cord is attached, which he holds in his left hand. Having in the boat a chaffer with small bits of iron red hot in it, he with a pair of nippers takes one of the bits of hot iron and drops it down the tube, which instantly ignites the powder and blows up the rock. A small part of the tube is destroyed next the cartridge, but the greater part, which is held by the cord, is reserved for future service. The workmen in the boat experience no shock by the explosion; the only effect is a violent eruptive ebullition of the water, arising from the explosion; but those who stand on the shore and upon any part of the rocks connected with those which are blowing up, feel a very strong concussion, similar to the shock of an earthquake. A certain depth of water is necessary for safety, probably at least 12 feet. The workmen cannot go down and work when the sea is very rough, as the swell would prevent them from settling on the bottom; and they are frequently annoyed with what is termed a *ground-swell*, when it is quite still at top. This is a sure prelude of a breeze of eastern wind, which seldom fails to set in soon after, if it has not prevailed at the time on the other side of the Channel.

The best and easiest time for going down is at low water, when there is less pressure; but amateurs prefer going down at high water, that they may have it to say that they were 20 or 30 feet below water in a diving bell. The workmen are generally down in the diving bell 5 hours in the day without coming up; and in summer one set of men are down ten hours one day, and 5 hours the other, and so on alternately. They work at all seasons of the year, and do not feel much difference in the temperature. The water is more chilly in the winter, and when they come up into the atmosphere they feel it rather cold after being heated by their exertions below. They do not complain in general of pains in the head, except those who are new to this employment, and they are at first affected in this way, and about the ears; but this soon wears off. The men are in general rather relaxed in their bowels, probably owing to their feet being constantly wet and cold. The superintendant stated he is generally troubled with looseness and a copious flow of urine, but that his appetite was greatly increased. He stated that he found it beneficial to take a little spirits on coming up; that the time never seemed long to him when below; that he has frequently been 7 hours under water, without ascending, and scarcely thought it half that time. None of the men became deaf, and it was thought in some cases to be of benefit to persons afflicted with deafness. One man who had been rather affected in his breathing was completely cured by *belling*.

DOCK. (Teutonic *dock*, from *dekken*, to cover, enclose, or protect.) An artificial basin or excavation for the reception of ships in rivers and harbours, for the purposes of repair, or for loading and unloading their cargoes out of the influence of the tide. They are constructed of brick, stone, or timber; with locks or flood-gates pointed to or from the tide, to keep the water in or out as may be required.

Wet docks are for the reception of ships to lie afloat while loading or unloading, with gates pointed from the tide, to keep the water in at low water. They are sometimes furnished with locks with double gates, in order to economise the water. A wet dock without

gates is called a *basin;* but this term is often applied to any form of wet dock.

Dry docks become so by the ebbing of the tide when the gates are left open, or by shutting the gates at low water, and pumping out the water that remains; this is now usually done by steam power. Ships under repair are placed in dry docks; they are admitted at high water, and the gates are shut at low water; and when the repairs are completed the gates are again opened before the rise of the tide, and the vessel is hauled out of dock. Ships are also built in dry docks called *slips.*

"Wet docks are an improvement in navigation and commerce of the utmost importance, but of very modern date in this country: indeed, they owe their introduction entirely to the spirit of individual enterprise in commercial speculation. Liverpool might still have remained a poor fishing village but for its convenient docks, which not only produce to the town and corporation a large revenue, but ensure to the merchant every possible facility in refitting, loading, and discharging his ships, whatever their burden or their cargo may be, without being exposed to the risk of losing both ship and cargo in a rapid tide river; and at all events to an unavoidable delay, occasioned by distance, the weather, or the state of the tides."

The most important docks on the Thames are the East and West India Docks, the London Docks, St. Katherine's Docks, and the Commercial Docks. There are also important docks at Southampton, Liverpool, and Birkenhead, Bristol, Hull, Dundee, Goole, Leith, &c. A valuable article on this subject, full of practical information, will be found in M'Culloch's "Dictionary of Commerce," 1850.

DORNOCK, a kind of stout figured linen, first manufactured at a town in Scotland of the same name.

DRAGON'S BLOOD, a resin of a deep red colour, imported from the East Indies. Professor Brande says:—"The finest kind is in large red drops or tears, and is said to be the produce of *calamus draco.* It also occurs in masses of various degrees of purity, and in sticks enveloped in palm leaves, but these varieties appear more or less adulterated. Pure dragon's blood is of a deep red colour, soluble in alcohol, and ether, and in alkaline solutions." It contains a little benzoic acid, and its chief use is for tinging spirit and turpentine varnishes, for preparing gold lacquer, for tooth tinctures and powders, for staining marble, &c.

DRAINAGE is an art of very great importance in works of civil engineering, and in rural domestic economy: its object is to collect and convey away the refuse waters and other matters from lands, towns, and buildings. By its means swamps and fenny districts are converted into fertile land; the health of the inhabitants, whether of town or country, is greatly improved; fevers and agues which once were common entirely disappear. The injury done by stagnant water to arable soil is shown by its effects, as thus stated by Mr. Stephens.[1] "While hidden water remains, manure, whether putrescent or caustic, imparts no fertility to the soil; the plough, the harrow, and even the roller, cannot pulverize it into fine mould; new grass from it contains little nutriment for live-stock; and in old, the finer sorts disappear, and are succeeded by coarse sub-aquatic plants. The stock never receive a hearty meal of grass, hay, or straw from land in this state, they being always hungry and dissatisfied, and of course in low condition. Trees acquire a hard bark and stiffened branches, and become a prey to parasitic plants. The roads in the neighbourhood are constantly soft, and apt to become rutted; whilst ditches and furrows are either plashy, or like a wrung sponge, ready to absorb water. The air always feels damp and chilly, and from early autumn to late in spring the hoar-frost meets the face like a damp cloth. In winter, the slightest frost encrusts every furrow with ice, not strong enough to bear one's weight, but just weak enough to give way at every step, while snow lies long lurking in shaded corners and crevices; and in summer, musquitoes, green-flies, midges, gnats, and gad-flies, torment the cattle, and the ploughman and his horses, from morning to night; whilst in autumn the sheep get scalded heads, and are eaten up by maggots, during hot blinks of sunshine. These are no exaggerated statements, but such as I have observed in every county in Scotland, in hill, valley, and plain; and wherever such phenomena occur, it may be concluded that stagnant water lurks beneath the soil upon a retentive subsoil."

(1) Manual of Practical Draining.

The same authority also states the benefits of thorough draining. He says:—"On drained land, the straw of white crops shoots up steadily from a vigorous braid, strong, long, and at the same time so stiff, as not to be easily lodged with wind or rain. The grain is plump, large, bright-coloured, and thin-skinned. The crop ripens uniformly, is bulky and prolific; more quickly won for stacking in harvest; more easily thrashed, winnowed, and cleaned, and produces fewer small and light grains. The straw also makes better fodder for live stock. Clover grows rank, long, and juicy, and the flowers large and of bright colour. The hay weighs heavy for its bulk. Pasture-grass stools out in every direction, covering the ground with a thick sward, and produces fat and milk of the finest quality. Turnips become large, plump, as if fully grown, juicy, and with a smooth and oily skin. Potatoes push out long and strong stems, with enlarged tubers, having skins easily peeled off, and their substance mealy when boiled. Live stock of every description thrive, show good temper, are easily fattened, and of fine quality. Land is less occupied with weeds, the increased luxuriance of all the crops checking their growth. Summer fallow is more easily cleaned, and much less work is required to put the land in proper order for the manure and seed; and all sorts of manures incorporate more quickly and thoroughly with the soil."

Mr. Black in his Prize Essay on Draining bears similar testimony. He is referring to the effects of

draining on the estate of Spottiswoode in Berwickshire. "Bursts and springs which formerly disfigured entire fields, and which rendered tillage precarious and unprofitable, are now not to be seen; and swamps, which were not only useless in themselves, but which injured all the land around them, have been totally removed. The consequence is, that tillage can now, in those parts, be carried on without interruption, and with nothing beyond the ordinary expenditure of labour and manure; and a sward of the best grasses raised and continued on spots which formerly only produced the coarsest and least valued herbage. . . . The hurtful effects of rime or hoar-frost on vegetation is a circumstance familiar to all who have had experience of cold and elevated districts, or of low lands subject to exhalations, excluded from the influence of the sun and currents of air. The rime in these swampy hollows was found, even in the warmest seasons, to be productive of serious inconvenience and injury to the growing crops; and that chiefly at the period when the grain was approaching its mature state. This evil, it may be said, has been removed, or at least is now so little felt, that the grain produced in these very hollows has for many years escaped the smallest perceptible injury from this cause.

"Another effect which was still less contemplated, and has not less agreeably resulted from the drainage undertaken, has been the improvement of the trees and woodlands on the property. Considerable difficulty was experienced in nursing up the trees in the first stages of their growth; and often individual trees grew up with stunted stems and covered with parasitical plants, which always indicate unhealthy growth. Latterly this evil has been infinitely less felt, owing in a material degree certainly to the superior management of the woods themselves, but obviously also in a certain degree to the great dryness of the ground. Since several of the woods have been laid dry by under-drainage, the ground in many of the hollows has sunk so much, that the roots of the trees have been left standing up bare above the surface, with the appearance of crow's feet; and parts which were boggy and marshy, and in which sportsmen used to stick fast in hunting, are now perfectly solid, with a good sward of grass, over which they may now gallop with freedom."

The art of draining is usually supposed to be restricted to the carrying off of water; but in its more extended sense it includes *irrigation*, or the proper distribution of water over a surface, with arrangements for carrying it off when it has served its purpose. Hence, if the natural supply of water be deficient, it is the duty of the drainer to increase it; if excessive, to reduce it.

The importance and value attached to supplies of water in Eastern countries are illustrated in many beautiful passages of Scripture, showing that water-springs, rains, and dew, were the most esteemed among earthly gifts, and therefore the most appropriate to be the figures of spiritual blessings. Other passages show that the art of irrigation was known to the earliest husbandmen. It has been supposed that the annual overflowing of the Nile, and the benefits derived to Egypt by that means, first suggested the idea of artificial irrigation to the Egyptians, and that other nations learned the art from them. The Egyptians practised the art on a large scale, as the remains of their canals and vast artificial lakes testify. Various hydraulic machines were also used, some of which appear to have resembled the water-wheels of the fen districts of England, and to have been worked by the feet of men, after the manner of the tread-mill. This laborious method of watering the ground seems to have been common in Egypt during the sojourn of the children of Egypt in that land, for Moses drew the following remarkable contrast between the climate and customs of Egypt, where rain seldom falls, and the more genial climate of the promised land. "For the land whither thou goest in to possess it is not as the land of Egypt, from whence ye came out, where thou sowest thy seed, and *waterest it with thy foot*, as a garden of herbs; but the land whither ye go to possess it is a land of hills and valleys, and drinketh water of the rain of heaven," Deut xi. 10, 11.

The method of raising and distributing water in Egypt at the present time is thus described. Water from the Nile is collected at certain times in large cisterns on the banks of the river. For this purpose the screw of Archimedes was formerly used, but now leathern buckets, or Persian wheels, are employed: these machines are placed all along the banks of the Nile, from the sea to the cataracts. When the grain crops, or the saffron, melons, sugar-canes, &c., require watering, a plug is taken out from the bottom of the cistern, and the water which gushes out is guided from one rill to another by persons whose office it is to manage the flooding of the ground.

Sometimes the water is merely raised by wicker baskets, lined with leather. Each basket is managed by two men, and is held by cords between them. Lowering and filling the basket at the river, they swing it over the banks into the canal, which conveys it at once to the land requiring water.

In Bengal the fields are diligently watered, or they would yield little produce. Wells are dug in the highest parts, and by means of bullocks, and a rope over a pulley, water is raised in buckets, and carried in small channels to every part of the field. Without this diligent watering of the soil in hot countries, rice, which furnishes food to the greater part of the human race, could not be cultivated. Accordingly, over the vast region of Southern Africa, the irrigation of the land by means of rivers, brooks, lakes, and wells, is a labour essential to human life. A machine similar to the Persian wheel is used in China for raising water.

In Southern Europe, also, irrigation is extensively carried on. In Italy, especially on the banks of the Po, it was practised long before the time of Virgil, and is zealously continued to this day. The waters of all the chief rivers of Northern Italy, as well as of numerous minor streams, are thus employed. From Venice to Turin, the entire country is said to be one

great water-meadow, for the watering is by no means confined to grass lands, but is conveyed into the hollows between the ridges in corn lands, is distributed over the lowlands, where rice is cultivated, and is carried round the roots of vines. It was from Italy that the practice gradually spread throughout the South of France, and from thence to Spain and Britain.

The conducting of water from rivers and canals, and measuring it out in certain quantities, is consequently an important business of Southern Europe, and also forms a nice part of the science of engineering. In Lombardy, the water of all the rivers belongs to the State. In the Venetian territories the government not only claims the rivers, but also the smallest springs, and even collections of rain water. In renting the water of rivers from government, contracts are made to pay so much for the use of the water for an hour or half an hour at a time, or for so many days at certain periods of the year. A person desiring to irrigate his lands has the right of making a canal through another estate, which may lie between him and the river, being bound, however, to pay the owner the value of the land, and to avoid bringing the canal close by the mansion, or through the garden of the proprietor. The rent of land having the means of irrigation is one-third higher in Northern Italy than that of lands not so provided. As may be supposed, the utmost care is bestowed in economising the precious fluid.

The principle of the system of irrigation adopted in Lombardy is shown in Figs. 724, 725, in which *a a* is the feeder to *b b*, the irrigating channels: the

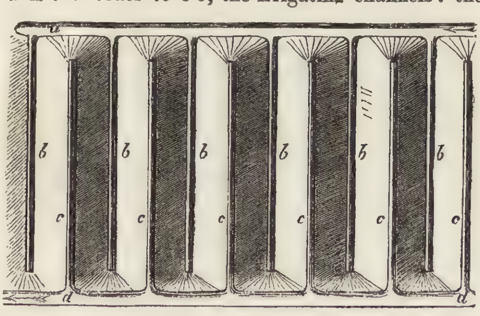


Fig. 724.

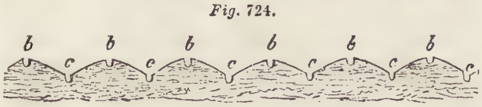


Fig. 725.

water overflowing from these spreads over the rectangular sections of land between them, and thence passes into the draining channels *c c*, formed at a lower level than the supply channels, and is received in the common drain *d d*, through which it passes, and becomes the means of irrigating and draining to other similar districts in succession. The width of land between the channels *b* and *c* is about 22 feet, and the difference of level between the irrigating and the draining channels about 6 inches. These water meadows are in this way irrigated in summer during several hours, about once a-week, and in winter, from the end of September to the end of March, the process is always in operation, except when the grass is being cut.

The methods of watering or draining districts and lands will vary with their respective levels; those adopted for high tracts being very different from low ones. As plains and valleys are more extensive than hill-tops and uplands, and are for the most part under cultivation, these necessarily receive a large amount of the drainer's care. Those low lands which form the margins of seas and rivers are frequently encumbered with a large surplus of water, which collects from the adjacent estuaries of large streams, or from rain or condensed vapour. If the level of the district is above that of the sea and the mouths of the rivers, the land may be kept tolerably dry by surface drainage. In some cases, the excess of water may be got rid of by tapping, or opening a communication with a lower and permeable stratum.[1] If the substratum be rock, surface-draining will succeed, but if it be bog, and its bed below the river or sea level, boring to the lower strata must be resorted to. If, however, the level of the district be below that of the waters, the land cannot be drained without embanking. In such case, in order to keep out the water, the embankments must be made substantial, and if the surface of the land cannot be raised to a higher level than that of the water, the surplus water must be got rid of by pumping. The system of embankments, carried on as it is to such a vast extent in Holland, has also been of great importance to our own island, by preserving its borders and extending its surface. In the fens of Cambridgeshire and Lincolnshire, the art of draining was at an early period forced upon the inhabitants as a matter of necessity. The bad effects of wet fields and moist pastures were recognised and deplored when the art of draining them was not understood in this country; "but on the sea-coast, and especially in the neighbourhood of the outfalls of rivers, the evil of neglect was too apparent to be disregarded: the ocean spread over its common bounds, and the waters of the river, choked up with silt, passed their limits; the pasture-fields became swamps; in some cases the land disappeared by degrees, and the inheritance of ages became merged in the boundless waters. The first work was to cut channels at intervals through the threatened district, (selecting the lowest levels for them where a choice was afforded,) in which the excess of water might be collected, and conducted to a main drain cut parallel to, or at an angle with, the coast or river; the transfer of the water from one to the other, and from the main to the sea or river, being, when necessary, regulated by sluices. The earth removed from these collecting and main drains, being cast up on either side of them, at once increased their available depth, formed boundaries to the passing water, and raised causeways for the passage of men and animals.

(1) An account of *drainwells*, as these openings are called, will be found in our article on ARTESIAN WELLS, p. 80 *ante*. A considerable portion of this article, as well as of the article AQUEDUCT, may be consulted in connexion with DRAINAGE.

Thus arose the combined arts of draining and embanking."[1] The reader who is interested in this subject will do well to study the accounts given of the various methods adopted for draining the districts of the fens, a short account of which may be appropriate here.

The *Bedford Level* is a term applied to a vast tract of about 400,000 acres of low land, extending into the counties of Northamptonshire, Huntingdonshire, Cambridgeshire, Lincolnshire, Norfolk, and Suffolk. It is bounded by high lands, which encompass it almost in the form of a horse-shoe. In that part of the Level which runs into Northamptonshire, and extends between Peterborough and Crowland, *Peterborough Fen* is situated, containing between 6,000 and 7,000 acres. One seventh part of the Level is situated in Huntingdonshire. Nearly the whole of the Isle of Ely, which forms the northern division of Cambridgeshire, consists of this marshy ground. The south-east part of Lincolnshire, usually named *Holland*, extending to the river Witham on the north, is a fenny district, included in the Bedford Level. 63,000 acres are situated in Norfolk, and 30,000 in Suffolk.

There is sufficient evidence to prove that at a much lower level than the present surface, the Bedford Level was formerly dry land. From natural convulsions, and, at a later period, from embankments improperly made, the waters from the uplands were prevented from flowing into channels through which they might discharge themselves into the sea; the consequence was that the tract became gradually reduced to the state of a morass, where the waters stagnating and becoming putrid produced miasma injurious to the inhabitants; while from the sedge, reed, and slime which covered this extensive district, it became impassable even to boats. At the time of the invasion of the Romans this Level was, probably, one of those vast forests to which the Britons fled for protection against their invaders, whose policy it was to cut down the trees, and thus destroy these native retreats. When the Romans became masters of the island they compelled the Britons to clear the woods, and embank the fens. The Roman emperor Severus, who died at the commencement of the third century, was the first who intersected these fens with causeways. One of these, extending from Denver, in Norfolk, to Peterborough, was 24 miles long, 60 feet broad, and composed of gravel 3 feet in depth. This causeway is now covered with moor from 3 to 5 feet in thickness. At that early period this low land, though damp, was not impassable; but up to the 13th century, it appears that the waters usually flowed in natural channels, and had not devastated the surrounding country. But in the year 1236, on the morrow after Martinmas day, and for the eight succeeding days, the sea was raised by a strong wind higher than its usual bounds, and it broke in at Wisbeach and other places, destroying many people, cattle, &c. A similar accident occurred 17 years after, and the king ordered the inhabitants to repair the banks: this does not appear to have been done very efficiently, for a few years after, they were again broken by the violence of the tides.

In the course of draining this district, abundant evidence was found of the previous vegetation, and that it was inhabited before the sudden catastrophe which overwhelmed it. "Oak trees were frequently found at a depth of 3 feet or more beneath the surface, lying near their roots, which still stand as they grew in the firm earth below the moor, and the bodies for the most part north-west from the roots, not cut down with axes, but burnt asunder somewhat near the ground. Some of these trees are 5 yards in circumference, and 16 in length, and many have acorns remaining near them. There are also fir-trees, which lie 1 foot or 18 inches deeper, many of them are more than 30 yards in length," and, according to Dugdale, one was taken out in the year 1653, "36 yards long without the top, which was lying near the root, which stood likewise as it grew, having been burnt, and not hewn down, which tree bore at the bottom 10 inches square, and at the top 8." A ladder of fir with about 40 staves, 33 inches asunder, was found in the moors at Thurne, and at Haxey Carr, a hedge with stakes and binders. Dugdale states that the buried trees are so numerous that the inhabitants have on an average taken up 2,000 cart-loads in a year. In making a deeper channel to the Wisbeach river, 8 feet below the then bottom, another hard, strong bottom was found, on which were lying 7 boats covered with silt. In digging through the moor at Whittlesey, in the Isle of Ely, for the purpose of making a moat, at the depth of 8 feet a perfect soil was found, with swaths of grass lying on it as they were first mowed. At Shirbeck Sluice, near Boston, a smith's forge was discovered buried 16 feet deep; the remains of several ancient tan vats were also found, besides a great quantity of horns, and some shoe soles, sharp-pointed in the fashion of those worn in the reign of Richard II.

In 1436 the project of draining these fens engaged attention. Large sums of money were expended in making the ditches and banks secure, but the next winter being wet and windy, the river Ouse, swelled into a torrent by tributary brooks, swept away all the bulwarks opposed to it. This accident long delayed the execution of the great project, which, however, was constantly being discussed by persons who favoured as well as by those who opposed the undertaking. It was not till the year 1634 that William, Earl of Bedford, undertook to drain this fenny district, (hence called the *Bedford Level*,) on condition that 95,000 acres of the reclaimed land should be allotted to him as a compensation for the expense and trouble incurred. In the course of 3 years 100,000*l*. were expended in the attempt, and the work was partially accomplished; the embankments, however, proved defective, and the whole was again allowed to lay waste until 1649, when the Earl once more attempted the task. 300,000*l*. were then expended in draining, embanking, &c., and

(1) "On the Drainage of Districts and Lands," by G. D. Dempsey, C.E. 1849. Published in Weale's "Rudimentary Series." This valuable little work has been of considerable assistance in preparing this article.

the work was successful, as far as the reclaiming of the land was concerned, but the sharers in the undertaking found that the 95,000 acres were of much less value than the sum expended in procuring them. From this time, however, a regular system was adopted for draining and preserving the land already reclaimed. In 1664 a company was incorporated for its management, consisting of 1 governor, 6 bailiffs, and 20 conservators; and to the present day the fens are managed and preserved by this corporation. Numerous cuts have been made, intersecting every part: some of these cuts are so large and deep as to serve for navigable canals. In the Isle of Ely the Old and New Bedford Rivers are two cuts running nearly parallel to each other, both navigable for upwards of 20 miles, from Erith to Denver. In draining the marshes the water is raised to the proper channel by machinery moved by windmills. In some cases these mills turn a kind of perpetual screw, made of wood several feet in diameter, mounted on a solid axle. This screw fits a semicircular trough, inclined at an angle of about 30° the lower part of which dips into the water below, and by its revolution discharges the water into a reservoir above. In this way the friction of pumps, and the wearing out of machinery is avoided. The mills require but little attendance, and work night and day whenever the wind blows.

Numerous projects have been adopted to complete and secure the drainage of the fens; and a vast expense has been incurred, sometimes much greater than the value of the land reclaimed. "In Huntingdonshire, about the latter end of the last century, the tax raised on the land by the conservators, for its drainage, and the preserving of its embankments, was in some instances so great, that the farmers preferred forfeiting their land rather than paying so exorbitantly for its preservation. In the present day the art of drainage is better understood than when first this stupendous work was undertaken; but even now, in many places, the farmer is still liable to have the produce of his grounds carried away by sudden inundations. The peculiar situation of the Level renders it the receiver of the waters of nine counties, and, therefore, it is difficult to provide a sufficient outlet to the sea by which the descending torrent may find a safe egress. The great error committed in the commencement of the drainage was the making numerous small cuts instead of larger and deeper channels, by which, with the same inclination of descent, the water would safely pour into the sea, without any risk of overflowing its banks; since in a narrow and shallow channel, owing to the smaller force exercised by the lesser body of water, the bottom must be made at a much greater inclination to cause the free flowing of the stream." Large and deep rivers run sufficiently swift with a fall of about 1 foot per mile, or 1 in 5,000. Smaller rivers and brooks require a fall of 2 feet per mile, or 1 in 2,500. Small brooks hardly keep an open course under 4 feet per mile, or 1 in 1,200, while ditches and covered drains require at least 8 feet per mile, or 1 in 600. Furrows of ridges and filled drains require much more.

We now proceed to give a few illustrations of the art of draining, taking in the first place the example of a level district with high land behind it. In draining this such an arrangement is made as is shown in Fig. 726, in which AB is the river, and CD the

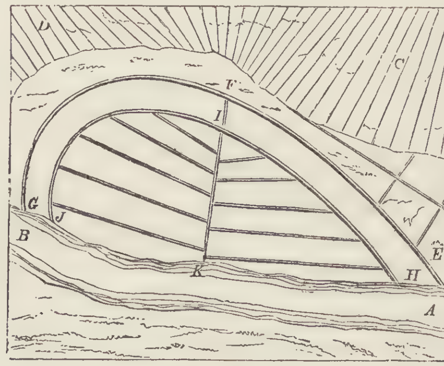


Fig. 726.

high land. EFG represent what is called a *catch water* drain, for receiving the waters from the high land. HIJ, a parallel main drain for the level with another main drain, IK. Between the main drains the level is intersected with minor drains, which have a fall either way towards the mains. The catchwater drain is adapted to discharge directly into the river; or, by closed sluices at EG, and an open one at F, its contents may be directed into the main level at I, and made to assist the irrigation of the level in dry seasons. Sluices will be required at E, F, G, H, I, J, and K, by the regulation of which the water may be collected and disposed of as required. The drains required for such works must be of large size. Drains of the sections shown in the following figures, with a

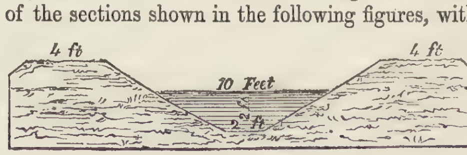


Fig. 727.

Fig. 728.

Fig. 729.

fall of 18 inches per mile, will discharge as follows:—Fig. 727, 10-feet drain, will discharge 1193.4 cubic feet per minute Fig. 728, 15-feet drain, 2,880 cubic feet per minute; and Fig. 729, 18-feet drain, will discharge 4,642 cubic feet per minute. Fig. 730 is a section for an embankment against the sea for works of this kind. E, the embankment of earth; W, a solid wall or dyke of puddle; M, a facing wall of masonry; S, high-water level of the sea or bay, and B, the natural

bed. The front wall is formed so as to resist the action of the waves, and the internal slope of the embankment must be adapted to the nature of the materials of which it is composed.

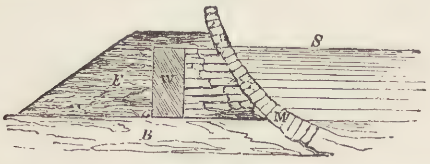


Fig. 730.

The waters both of the nigh and of the low lands being thus discharged into the river, it is of great importance that the channel of the river be of sufficient dimensions, and of the proper form to maintain an active and sufficient current through it, for which purpose there must be a direct course, and a sufficient fall for the channel. "If the direction be tortuous, the projecting banks will be washed into the bed, and impede the flow of the current, and if the bed be on a dead level, or have an inadequate inclination, the flow will be sluggish, and lend no assistance to the discharge. Besides these conditions, it is necessary that the outfall of the river into the sea be of ample dimensions, and unencumbered with shoals, bars, or other solid accumulations." [See Dredging.] If the outfall be unimpeded, 4 or 5 inches per mile will be a sufficient fall, but if the channel be obstructed by old bridges, bendings, &c., as much as from 12 to 18 inches per mile will be required.

As important works of this kind, Mr. Dempsey instances those for improving the rivers Ouse and Nene. The chief defect in the former existed above the town of Lynn, where the river turned almost at right angles to its general course, and in a length of $5\frac{1}{2}$ miles formed a semicircle of only $2\frac{3}{4}$ miles in diameter. The channel was also so irregular in width, and encumbered with shifting sands, that the tidal and drainage waters were unable to force a passage, and disastrous inundations were the result. In 1724, the proper remedy was proposed, viz. by making a direct cut, which should intercept the bend; but it was not till 1817 that an Act was obtained for executing this important work, which was named the Eau Brink Cut. The late Mr. Rennie was the engineer. The works were finished on the 19th July, 1821, and their effects have proved highly successful: they have lowered the low-water line in the river several feet, and have completed the drainage of upwards of 300,000 acres of land. A similar work was executed in 1829 by Telford and Rennie, at the outfall of the river Nene, which commences about five miles below Wisbeach, and terminates after a length of five miles in the great estuary of the Wash. The effects of this improvement have been to lower the low-water mark $10\frac{1}{2}$ feet, and to bring a district of upwards of 100,000 acres, which was a stagnant marsh, into cultivation.

Connected with the drainage of low lands are the operations by which land is reclaimed from the action of the sea. The alluvial matters brought down with the drainage waters and thrown back by the tide, are collected into embankments for the purpose of restraining the advance of the waters. Embankments are also required in districts which lie below the level of the adjacent river, or so little above it that the beds of drains are below the water-line. Artificial means are then resorted to for discharging the drainage waters into the receiving channel or river. For example, in Fig. 731, L represents the general level of the district, D that of the water in the drain to be discharged, E the top of the embankment, and H the high-water level outside. In order to transfer

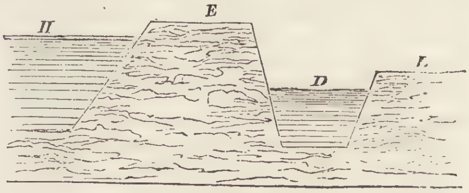


Fig. 731.

the contents of the drain D into the main channel H, such machinery is erected on the embankment as will bring the water up on one side and discharge it on the other. The Dutch, who carry on this method of draining extensively in their low lands, employ scoop-wheels worked by means of windmills, as already noticed. Mr. W. Fairbairn, however, has contrived a new form of scoop or alternating trough, adapted to be worked by the single-acting Cornish engine. The bail-scoop S, Fig. 732, turns on a centre at C, fixed on the embankment E: the other end of the

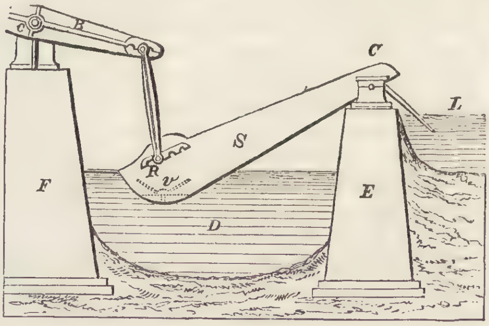


Fig. 732.

scoop is connected at R by a connecting-rod with the end of the engine-beam B, of which *c* is the centre, and erected on suitable foundations, F. L is the level of water in the river, and D the drain from which the water is to be discharged. The engine is of the reciprocating kind, and by raising a weight suspended at the other end of the engine-beam B, the scoop S descends, and becomes filled with the drainage water through the opening valves at *v*. The weight having been raised to the height of the stroke, descends by its own gravity, and raising the end R of the scoop, discharges its contents into the river at L. By shifting the connecting-rod at the two ends the dip may be regulated. The scoop is made of iron boiler-plates, and is 25 feet long and 30 wide, with two partitions across it, to strengthen the sides and afford bearings for the valves at *v*. 17 tons of water can be raised at each stroke by this machine, and with

an engine of sixty-horse power will do a duty equal to three pounds of coal per horse power per hour.

The application of the steam-engine to drainage is one of the greatest improvements that have been introduced into the arts. In 1820, Mr. Rennie applied one of Watts's engines to the working of a large scoop-wheel, for draining Bottisham Fen, near Ely. Since that time, large districts have been effectually drained by steam power. Such, for example, as Deeping Fen, near Spalding in Lincolnshire, containing 25,000 acres: this was drained by means of two engines, of 80 and 60 horse-power. Littleport Fen, near Ely, containing 28,000 acres, was drained by two engines, of 30 and 40 horse-power, taking the place of 75 wind-engines which were formerly used. Middle Fen, in Cambridgeshire, 7,000 acres, was drained by one engine of 60-horse power. Many other examples could be cited.

"If the drainage from the high lands be discharged through catch-water drains, that from the low levels will consist of the rain-water only; and as this in the fen districts on the eastern side of England seldom exceeds the average of 26 inches in depth per annum, of which a large quantity is carried off by evaporation and absorption, 2 inches in depth, or $1\frac{1}{2}$ cubic feet of water on every square yard of surface, is the ordinary maximum quantity to be lifted per month. Adopting the admitted standard of horse-power, viz. 33,000lbs. raised one foot per minute, and the weight of a cubic foot of water to equal $62\frac{1}{2}$lbs., or 10lbs. per gallon, a horse's power will raise 330 gallons, or 52.8 cubic feet of water 10 feet high per minute. The total quantity to be raised per acre per month, viz. 7,260 cubic feet, may thus be raised a height of 10 feet and discharged in about 2 hours and 10 minutes. Upon this calculation, which Mr. Glyn has found to be supported in practice, it appears that a steam-engine of 10-horse power will raise and throw off the drainage-water due to a district of 1,000 acres of fens, in each month, in 232 hours, or less than 20 days, working 12 hours a-day."

The power of the steam-engine has been nowhere more admirably illustrated than in the drainage of some of those extensive fresh-water lakes, such as the Lake of Haarlem, in Holland, for the purpose of cultivating the site which they occupy. The plan adopted by the Dutch government for draining this lake was that recommended by Messrs. Gibbs and Dean, who proposed to employ three engines of great power. One of the engines which has been erected works 11 pumps simultaneously: the net weight of water lifted is 81.7 tons, and the discharge, 63 tons per stroke. By working the 11 pumps without regard to economy of fuel, it was found that 109 tons of water could be raised per stroke to the height of 10 feet.

In draining the lands of valleys in which natural watercourses, such as rivers, &c., exist, the inclination of the surface towards the stream will indicate the method to be adopted. If the surface be comparatively level, the beds of the drains may be parallel or nearly so to the surface, and arranged to deliver into one or more main drains with lower beds, but still above the low-water level of the receiving channel. If the surface undulate, the main drains must be laid in the hollows, and the feeders be distributed over the high parts and made to communicate with the mains. By means of small sluices fixed at intervals in the main and minor drains, the water may be made to accumulate for the purpose of flooding or irrigating the higher lands. Fig. 733, is a plan, and Fig. 734 a section of a district so arranged. R R′ is the river or receiving channel, D D′ the principal main drain,

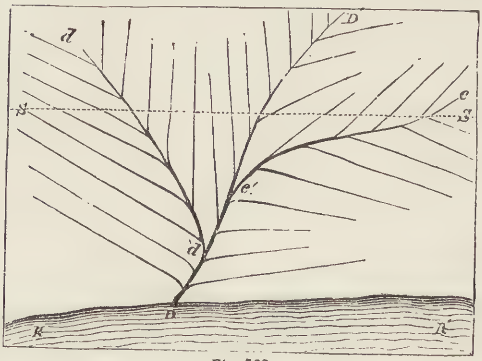


Fig. 733.

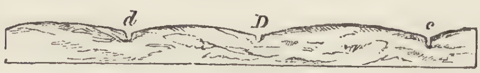


Fig. 734.

and *c c′*, *d d′* two other main drains delivering into it; each of the mains receiving the drainage from the feeders or minor drains. The section Fig. 733, is supposed to be taken on the line s s′ on the plan. In such arrangements as these it is necessary that all the junctions be curved, and that no two feeders enter the main drain at opposite points. Unless these precautions be attended to, the currents will be interrupted at those points, and flooding be produced in wet seasons. The junctions should also be guarded with a few rough stones piled together in the form of a retaining wall, or even concreted with lime and gravel.

When the general inclination of the surface is considerable, it may be desirable to form catch-water drains, or series of drains at different elevations communicating with each lower one in succession by means of falls. In this way the waters are under control, and the falls may even be used as water power.

It was formerly the custom to drain only on very wet and marshy soils; but at the present day it is often had recourse to with the best effects on land that externally appears dry. The fact is that stagnant water frequently exists underneath the surface, injuring the crops and sending up reeds, rushes, or rank grass to betray its presence. Drainage in such a case promotes healthy circulation, and is of the highest importance, as will be seen from the opinions of the competent authorities quoted at the commencement of this article. The simplest kind of drain, as already noticed, is a mere cut or channel in the surface of the ground; but this is useful only to carry off rains and surface waters: the more complete form

of under-ground or covered drain conveys away the superabundant moisture from the body of the soil. The Romans were acquainted with both forms of drain, and their earliest agricultural writings give particular directions for making them. In our own country there is no distinct mention of draining until the reign of William the Conqueror, when it is stated that a great extent of country was drained by the king's chamberlain, the Lord of Brunne and Deeping. A book published in the reign of Henry VIII. gives minute directions for draining; but the art was imperfectly known and practised until the close of the last century, when a new system was introduced by a practical farmer named Elkington, and this system has been the foundation of numerous others in practice at the present time. The first idea of Elkington's method is said to have been suggested to him in the following manner:—One of his fields being very wet, so that sheep fed in it became afflicted with the rot, he dug a trench four or five feet deep to discover the cause of the mischief. While he was examining this trench, a servant passed by with a crow-bar for fixing sheep-hurdles in the ground. Elkington took the crow-bar and plunged it into the bottom of the trench, to discover, if possible, what lay beneath. The crow-bar sank deep, and on pulling it up, to his astonishment a great quantity of water welled up through the hole which it made, and flowed along the trench. Thus he discovered that large bodies of water may be pent up beneath the soil, and may be let off by tapping with an auger or rod. Applying his knowledge of this fact with great skill and sagacity, Elkington became famous for his system of drainage, which when compared with the old method was found as much more effectual for the purpose as blood-letting is more effectual on the human constitution than the local application of leeches. By making a few deep drains and boring in the most essential spots, he performed the work much more perfectly than he could have done by numerous conduits near the surface. Although not a scientific man, he was gifted with natural shrewdness and powers of observation which enabled him to detect the seat of springs, a most difficult task, and to apply the proper remedy.

There are three leading varieties of soil to be considered in drainage, for according to their relative position the mode adopted will vary. These are the *porous* soil, the *retentive* soil, and the *mixed* soil, which partakes of the qualities of both. A common arrangement of these is for the porous, P, Fig. 735,

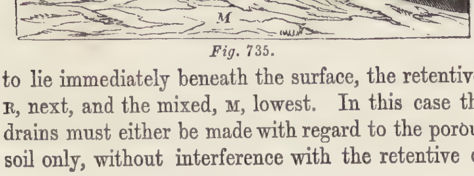


Fig. 735.

to lie immediately beneath the surface, the retentive, R, next, and the mixed, M, lowest. In this case the drains must either be made with regard to the porous soil only, without interference with the retentive or clay, or the main drains must be made completely through the clay, which will bring the land into a much drier condition. Boring in the wettest places may also be resorted to. In other cases, where the clay or retentive soil, R, Fig. 736, is uppermost, and

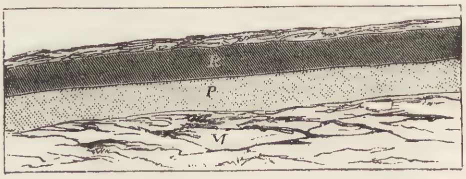


Fig. 736.

the porous soil, P, underneath, it will be imperative to cut the drains entirely through the clay, and if the porous soil be shallow, to cut them through that also. Where the clay bed is too thick to be cut through, numerous small drains must be made, to free the clay as much as possible from excess of moisture. If a tongue of porous soil, I, Fig. 737, lie upon one of

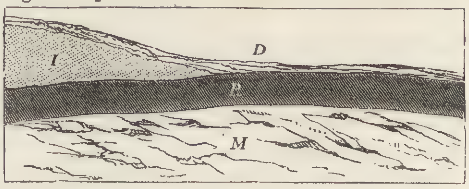


Fig. 737.

clay, no drainage of the former will have any effect, but a main drain, if possible, entirely through the clay at the point marked D, will be the remedy needed. If a similar tongue extend under and amidst the clay, as at P, Fig. 738, there must be not only a drain

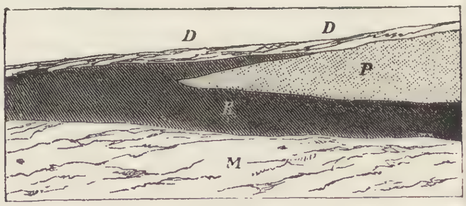


Fig. 738.

through the clay over the tongue, but another at the foot of the tongue also, as at the points D D. So, also, where beds of gravel or other porous material lie in the midst of a retentive bed, two sets of main drains will be, in like manner, required.

Surface drains are sometimes open, and are proportioned in size to the quantity of water they have to carry away. Their sloping sides, however, occasion much loss of soil. The simplest kind of covered drain is a trench two or three feet deep, filled with stones and rubbish to within a foot of the surface. An improvement on this is when the stones are arranged in such a manner as to leave an open conduit at the bottom. This is still better effected when a semi-cylindrical tile is placed on a flat tile, and occupies the lowest part of the drain, as in Fig. 739; or if slate is plentiful, this will be cheaper than the flat tiles, and will answer the same purpose, namely—to prevent the arched tile from pressing into the soil, and so becoming useless. Another form of conduit

is shown in Fig. 740. In laying these flat tiles or

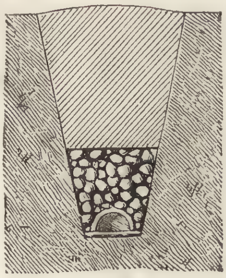


Fig. 739.

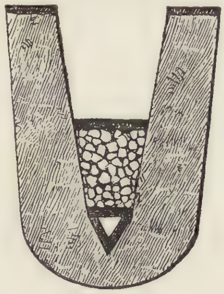


Fig. 740.

soles, as they are called, care is taken not to let their joints correspond with those of the drain tile. See Fig. 741. At regular distances, where branch

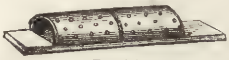


Fig. 741.

drains are to enter the main, a tile is used for the latter which has an opening in its side, into which the branch drain is exactly fitted. Drain-tiles of a cylindrical form, or of a form embracing that of a sole and tile in one, are now much used. The chief danger is of their slipping apart at the joints and thus spoiling the drain. Sometimes this is provided against by a

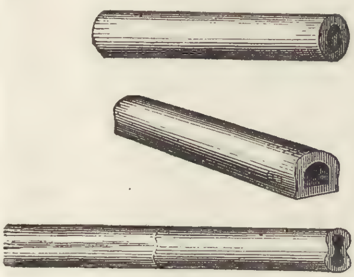


Fig. 742.

sort of collar covering the joint; sometimes by making the ends of the cylinders lobed or waved so as to fit into each other. See Fig. 742.

In deep draining the processes already noticed are performed on a larger scale. The conduit at the bottom is built securely by a person who understands the construction of dry stone walls, and the drain is filled up with stones, having a layer of turf, coarse grass, or dry leaves over them, before the soil is covered in. Boring is frequently resorted to, and a common auger, a sharp pyramidal punch, and a chisel or jumper are all required. [See BORING.] The three leading points in deep draining in which Elkington's peculiar skill became remarkable were, first, finding out the main spring, or cause of the mischief; secondly, taking the level of that spring, and ascertaining its subterraneous bearings; and, thirdly, making use of the auger to reach or tap the spring, when the depth of the drain was not found sufficient to answer his purpose. Skill of a similar kind to his is required to conduct deep draining with good effect, otherwise great expense may be contracted to little purpose. The tapping of the soil is, of course, only available where the spring is fed from a higher level, so that the pressure may force the water up through the auger-hole. Sometimes, as a substitute for the auger-hole, a well is formed and filled up with loose stones, through which the water rises and passes along the drain. Similar wells are sometimes formed for the opposite purpose of conveying the water from surface drains through a retentive soil into a more porous one beneath. The varieties in draining are, indeed, almost endless, and the locality to be operated upon should be closely studied before the precise mode of working be decided on. Surface drains must be placed lower than the plough will penetrate, or they will be constantly liable to disturbance. In forest land drains must be open, for covered ones are soon rendered inefficient by the roots of trees penetrating and choking them. The dimensions and distance apart of the several drains must be determined entirely by the nature of the soil, and the amount of water to be carried off. An average scale for determining these points has been drawn from experience on various soils, and is given as follows in Mr. Dempsey's treatise:—

CHARACTER OF SOILS.	DRAINS. Depth. Ft. In.	Distance apart. Ft.
COMPACT.		
Tenacious clay	2 6	15
Friable clay	2 9	18
Soft free clay	2 9	21
MEDIUM.		
Clayey loam	3 0	21
Gravelly loam	3 3	27
Friable loam	3 3	30
POROUS.		
Light loam	3 6	33
Sandy loam	3 9	39
Light gravelly sand	4 0	51
Coarse gravelly sand	4 6	60

The cost is also estimated as follows:—

No.	SOILS.	Depth of Drains. Feet.	Distance between the Drains. Feet.	Cost of Labour per Acre. £ s. d.	Cost of Pipes or Tiles per Acre. £ s. d.	Total Cost per Acre. £ s. d.
1.	Clay	—	15	2 11 4	3 0 11½	5 12 3½
2.	Sandy clay	—	18	2 2 10½	2 10 9¾	4 13 8½
3.	Ditto	—	21	1 16 9	2 3 6½	4 0 3½
4.	Free stony subsoil	—	24	1 12 1	1 18 1½	3 10 2½
5.	Ditto	—	27	1 8 7	1 13 10¼	3 2 5¼
6.	Porous	—	30	1 5 8	1 10 6	2 16 2
7.	Ditto	—	33	1 3 4	1 7 8½	2 11 0½
8.	Sand or gravel	—	36	1 1 7	1 5 4	2 6 11
9.	Uniform clay	3	33	1 0 0	7 11	1 7 11
10.	Ditto	3	33	1 0 0	7 11	1 7 11
11.	Ditto	3 to 4	33	1 6 8	7 11	1 14 7
12.	Ditto	3½ to 4	40	1 2 0	6 6	1 8 6
13.	Clay, with some stones	4	50	1 6 6	5 3	1 11 9
14.	Clay: hard gravelly subsoil	3 to 3½	49½	1 15 6	5 4	2 0 10
15.	Ditto	4	49½	1 15 6	5 4	2 0 10
16.	Various: clay, gravel, sand	4	66	1 6 8	4 0	1 10 8
17.	Clay: gravelly subsoil	3½ to 4	33	2 10 0	7 11	2 17 11
18.	Heavy clay	4	36	—	—	4 11 7
19.	Various clay	4	36	—	—	3 15 5
20.	Strong clay	4	30 to 33	—	—	4 4 2
21.	Strong land	4	39	—	—	4 15 7
22.	Weak blue clay	4	30	—	—	4 13 11
23.	Whitish stubborn clay	4	36	—	—	4 16 1
24.	Strong clay and gravel	4	33 to 36	—	—	5 3 4
25.	Whitish clay	4	36	—	—	4 4 8

The drainage of houses and towns will be noticed under the article SEWER.

DREDGING, an operation for loosening and lifting the mud, gravel, sand, clay, stones, &c., which are deposited, or may have formed the original stratum of the bed of canals, rivers, docks, harbours, &c.

"If the universal tendency to waste and decay in the higher lands, from the agency of moisture, heat and frost, be considered, we shall find that every rill of water must carry along with it a portion of separated matter. These rivulets being so many tributary streams to the great rivers, which form the drainage of vast tracts of country, we need not be surprised to find that the beds and embouchures of the Scheldt, the Meuse, the Rhine, and the Elbe, or of the Thames, the Humber, the Tay, and other great tributaries to the German Ocean, should be variously silted up; and that even this great basin itself should be much encumbered by numerous banks of deposited matters. To the agency of these, combined with the effects of cross-running tides, we ascribe the existence of the Dogger Banks, the Yarmouth Sands, the Flemish Banks, and even the great platforms of Holland, and the opposite planes of the Fens of Lincoln. There is also a marked difference to be noticed in the separation and distribution of these matters of deposition. In those rivers which flow with a very gentle current toward the sea, fine silt, or what is sometimes termed *ouse*, is produced; while rivers of greater fall, and consequently of more velocity, carry forward the grosser particles proportionally further from their embouchures. Another circumstance which deserves our notice is the greater specific gravity of salt-water than fresh, which preserves their course in distinct films, the salt-water under the fresh. The salt-water thus flows up the courses of the respective rivers to an extent corresponding to the fall of their beds and the rise of the tide. A considerable portion of the heavier matters, as gravel and sand, are arrested in their progress sea-ward when the current is languid; while the lighter particles, floating at or near the surface, are either borne along with the stream into the expanse of the ocean, or settle in the eddy waters. In this way the projecting obstacles along the margin are formed, and thus accumulate in the form of sand-banks and small islets; the creeks and sinuosities are also silted up, and too often render the connecting harbours and shipping places so shallow, as to be unfit for the purposes of floating ships of burden. To such a degree has this been experienced in some situations, as for example, Sandwich in Kent, that this ancient sea-port is left almost in the state of an inland town; while other ports have been more or less deteriorated."[1]

The various methods of dredging may be arranged into two great classes, the natural and the artificial, the former of course being preferred where circumstances admit of it. The great natural agent in dredging are the drainage waters of the connecting district, and the flow of tidal waters, the former being judiciously applied, and the latter preserved in full and ample flow. For example: at Montrose, in Forfarshire, some of the proprietors have from time to time proposed to make firm ground of the great natural basin connected with the harbour of that port. This basin is flooded every tide to the extent of about 5 square miles, and is estimated, especially in spring tides, to contain about 55,000,000 of cubic yards of the back waters of the tide, which passing 4 times in the 24 hours through this harbour, produced so powerful a current, that the shifting sand-bank at the entrance, called the *Annet*, is prevented from being thrown across the mouth of it in gales of easterly wind. In this state of weather, the Annet-bank has a continual tendency westward, while the back-waters of this great natural basin check its progress, and not only keep the navigation open, but are sufficient to preserve a considerable depth in it during the lowest tides.

Such powerful and valuable means of keeping open ports and harbours are often entirely destroyed by the desire of acquiring land, which leads to the erection of embankments, whereby the back waters arising from the flow of the tide are shut out. The importance, however, of such means has long been recognised by engineers, who in their designs of tide-harbours often introduce scouring basins, as at Ramsgate, Dover, &c. At the latter place this plan is so successful that the entrance to the harbour, which has been quite shut up, has been cleared, and rendered accessible to packets in the course of a few hours. In some cases drainage-water has been kept back by gates, and used as a back-water to scour and keep open the entrance of harbours on our eastern coast, which are very liable to be choked up in stormy weather from the action of the sea upon the sand-banks which encumber the coast. In extensive plans of docks, use is made of a system of sluices for scouring and floating away the mud.

Dredging by artificial means seems to have been first practised by the Dutch for clearing the bars or entrances to their harbours and navigable canals. The first machines employed merely loosened, but did not raise the stuff, a scouring being afterwards effected by means of sluices. These machines consisted of large bars or prongs placed vertically in a frame, and being fastened to a barge placed in the line of the sluices, the whole was impelled forward by the current, thereby scouring the bed. Such a machine, called a *hedgehog*, is still used in Lincolnshire.

One of the earliest dredging machines employed in Britain, consisted of a large plate of iron about 4 feet long and 18 inches deep, sharpened on the under edge. To each end of this plate was attached a plank of hard wood, the sharpened edge of iron projecting about 4 inches below the wooden sides, and a bar of iron supported the other two ends of the wood, and kept them stretched. The machine was something like a box without top or bottom, 18 inches deep at one end, and 10 inches at the other. From the two extreme points of the wood was fixed a chain for attaching the principal working rope or chain. By drawing this machine across the river by means of a capstan or windlass, it becomes filled, and

(1) Encyclopædia Britannica; article, *Dredging*.

the men shovel out the stuff on the bank. The operation of this machine is slow and tedious, and it is seldom used except in levelling foundations under water when the material is soft; but by forming the mouth of the dredge of curved bars of iron, gravel and stones can be dredged out.

For some years the convicts at Woolwich were employed in deepening the river Thames, and obtaining stuff for ballast, or for embankments, &c. by means of the *bag and spoon.* The spoon is a ring of malleable iron 2 feet wide and 2 feet 4 inches deep, sharpened and steeled on the under side for about one-third of its circumference, and pierced on the inner edge with holes for the lacings of the bag. On the upper side a hose is welded for receiving the pole or handle, and from each side about halfway up the spoon is fastened a chain $2\frac{1}{2}$ feet long. These chains meet in a small ring in the middle. The bag is usually of leather, tapering to the depth of about $3\frac{1}{2}$ feet. It is laced to the spoon with leather thongs, and perforated to allow the water to escape. The spoon is worked from the deck of a flat barge or lighter, mounted with a small projecting crane-work. A rail is also placed to assist the spoon-holder. A snatch-block is also used at the end of the barge away from the crane. It is fixed at the end of the barge, and the rope passing through it is attached to the bottom of the bag.

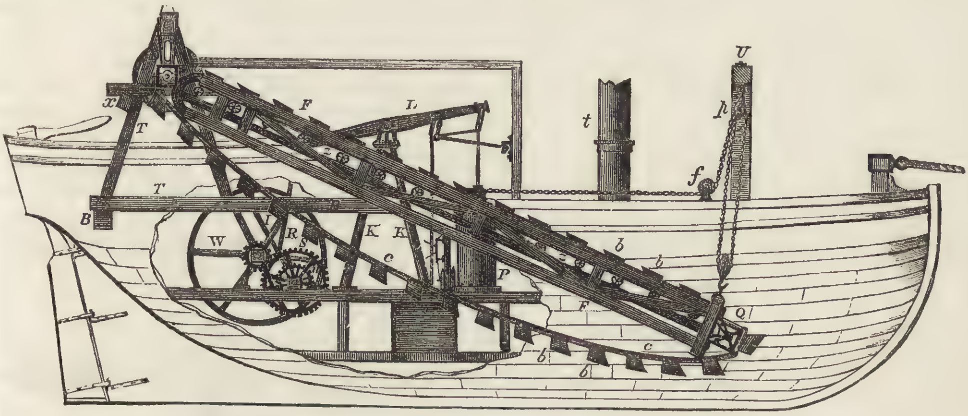


Fig. 743. ELEVATION AND PARTIAL SECTION OF DREDGING MACHINE.

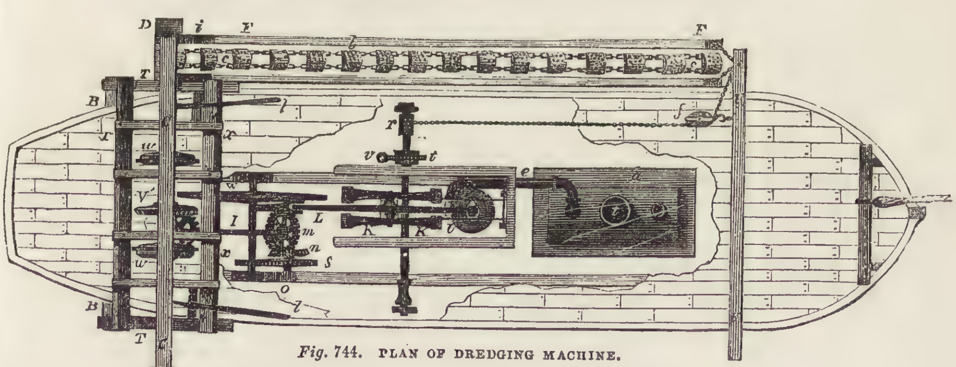


Fig. 744. PLAN OF DREDGING MACHINE.

The working-rope being fastened to the chain of the spoon, and the other end to the barrel of the crane, the man who is stationed at the handle or pole tumbles the spoon into the water. The man at the crane throws it out of gear, when the third man seizes the small rope, which is reeved through the snatch-block, and fastened to the bottom of the bag, with which he runs along the gunwale, and prevents the spoon and bag from sinking until it gets near the other end of the barge, when the man at the pole turns it up, inclining the pole head towards the crane-end of the barge, takes a turn with a small rope round the pole and rail, which keeps the spoon dredging along in its proper position, while the man at the crane draws along the spoon until it is nearly under the crane, when the man at the pole inclines it backwards, and the contents, now deposited in the bag, are hoisted up and emptied into the barge.

As all rivers, harbours and canals, have a tendency, greater or less, to fill up, it is of the first importance in a commercial country like Britain, to have dredging machines of great power to preserve them open. Such a machine is shown in Figs. 743, 744. Fig. 743 is an elevation and partial section of the machine, showing the steam-engine, and wheel-work within the vessel. Fig. 744 is a horizontal plan. This machine, which is erected in the hulk of an old sloop, has two chains of buckets, one on each side of the vessel, but only one of them is shown in Fig. 744. These endless chains revolve on rollers, placed at the two extremities of strong frames of timber F F, which rise and fall on a centre at their upper ends, their weight being sus-

pended by pulleys *p p*, which being lowered down, allow the buckets *b b*, attached to the chain *c c*, to reach the bottom. B B are two beams projecting a short distance from the sides of the vessel at the stern, upon which are mounted two triangular frames T T, for sustaining a strong timber C, extended across the vessel: these with their cross timbers X X form a frame, which supports all the machinery above deck. The beam C is as long as the whole width of the machine, and at each end of it is a cast-iron bracket D D, hanging downwards, for supporting the upper end of the bucket frames F F, and also the centres for the chain-barrels over which the endless chains revolve by the motion of the machine. The bucket frames F F are each composed of 4 long timbers, bolted together, and braced by diagonal stays *s s*. The pulleys *p p*, suspending the lower end of the chain frames, hang from the beam U U, which extends across the vessel, supported on the top of vertical posts erected on the deck. The upper end of each of the chain frames F F has 2 stout iron semicircles *i i* bolted to the timbers and terminating in rings or eyes fitted over two tubes or hollow iron centre-pins, one supported by the bracket D, the other by the frame T. On these pins, the frame hangs as upon a centre at *o*, and can be raised or lowered at pleasure. The upper roller for the endless chain is a square barrel, and revolves upon the same centre *o*, and a similar square barrel of the same dimensions is placed in bearings at the lower end of the bucket frames Q: the double endless chain *c c* passes round both these barrels, and every other link of these two chains carries one of the buckets *b*. Each bucket is made of plate-iron, and is pierced full of holes, to allow the water to drain out of the gravel, as they come up: the mouth is semicircular, which renders it less liable to stick fast in the ground, than if it was square. A number of iron-rollers *r r*, are placed on the inside of the beams of the chain frame, to support the weight of the chains and buckets, as they pass up. The upper chain barrels for the frames on both sides of the vessel, are in a line with each other, and both receive their motion from the steam-engine which is situated in the hold. *a* is the boiler set in brick-work, with the fire beneath it, and a wrought-iron tube *t*, carried up to the proper height, is the chimney: *e* is the steam-pipe communicating from the boiler to the engine: P is the cylinder, L the working beam or great lever, the centre of which is supported by 4 iron columns K K. The connecting rod R of the engine is jointed to the extremity of the beam L, at the top, and at the other end to the crank on the extremity of the shaft O. The fly-wheel W of the engine is turned by the large spare-wheel S, fixed upon the shaft O, acting in a pinion on the axis of the fly-wheel. The motion is conveyed from the engine to the chain barrels, by an inclined shaft T, the lower end of which has a bevelled wheel *m*, receiving motion from the wheel *n*, fixed on the main shaft of the engine. At the upper end of the same inclined shaft is a bevelled wheel V, working another, V′, fixed upon a shaft, situated in a line with the centre of the two chain barrels. At the two extremities of this shaft, two circular iron plates or wheels are fixed at *w w*: these are received into boxes or hollow wheels attached to the extremities of two other shafts placed in a line with the former, and leading to the chain barrels. These boxes and wheels form a connexion between the several parts of the shaft, and by the friction of the wheels, which are accurately fitted to the boxes, a sufficient power is communicated to turn the chain barrels round, and bring up the gravel; but should the buckets take too deep a hold in the ground, these boxes will slip, and thus prevent the chain from being broken. *l l* are levers which operate on coupling boxes on the main horizontal shaft, and give the means of disuniting either of the chain-barrels at pleasure, while the other continues at work. The blocks of the pulleys *p p*, which suspend the great bucket frames, are reeved with a chain, the fall of which passes through the match-block *s*, fixed down upon the deck, and then winds round the roller *z′*. This is turned by the engine, its axis having a worm-wheel *t* fixed upon it, turned by the worm *v*, and shown on a larger scale in Fig. 745. This worm is formed upon the inclined spindle I, but is represented here to avoid confusion.

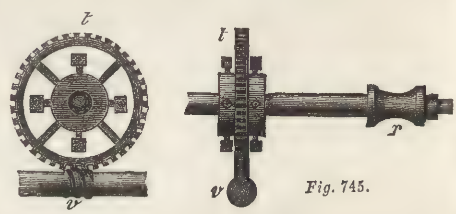


Fig. 745.

The vessel containing this machine is moored in the stream by the head or stern, or both if it be required to work across the stream. The engine being put in motion, the chain frames are lowered down by giving out the chains of the pulleys *p p*, until the buckets drag sufficiently upon the bottom to become filled with ballast in their passage, and come up along the top of the frames by the motion of the chains, till they turn over the upper chain barrels and discharge their contents into large hoppers or troughs, suspended by ropes from the beams T T and C, and being placed somewhat inclined, the troughs conduct the gravel into barges moored beneath. The motion of each chain is managed by one man, who stands near the end of a long lever which supports the pivots of the worm-wheel *t*, so that by moving the end of this lever, the wheel can be disengaged from the worm to give it motion or set it at rest. There is also a gripe or brake wheel, not shown in the figures, fixed upon the spindle of the roller *z′*, to prevent the roller running back by the weight of the chain frames when the wheel *t* is disengaged from the worm. The wheel *t* is attached to its spindle by friction only, so that it can slip if overstrained without breaking the teeth; but it is furnished with adjusting screws, Fig. 745, to give sufficient friction to raise the required load without slipping.

By means of the levers the attendant can cause the buckets to go as deep as may be desirable, and

as they deepen the channel he gradually raises the gripe-lever, which allows the frame to descend lower down: but if the buckets meet with an obstacle, or take such deep hold as to stick fast, he engages the wheel *t* with the worm by means of the lever, and this winds up the chain of the pulleys *p p*, till the end of the frame is raised sufficiently high from the bottom to disengage the buckets, which then resume their motion, and the wheel *t* is then immediately cast off from the worm, because it is not necessary to raise the frame higher: by relieving the brake-lever it can be again lowered to reach the bottom. There are two other rollers similar to *t*, placed just above the deck, and kept in slow motion by the engine for the purpose of advancing the engine along in the water. A strong rope attached to a mooring block or anchor placed at some distance up the stream, is passed round the roller: a man *holds on* the end of the rope as in a capstan, and thus the whole engine is slowly brought up as the channel is dredged and advanced to operate on a fresh portion of the bed. The above machine working at a moderate depth with an engine of 16-horse power, will bring up enough in an hour to load two barges of 35 tons each. The bucket frame works best at an angle of about 45°; machines of this kind may be used for bringing up sand, mud, clay, gravel, and even stones of considerable size.

In the Humber Dock at Hull, the quantity of mud annually deposited is said to have amounted to 36,000 tons. By means of a dredging machine with 29 buckets, as much as 60 tons per hour can be raised. An engine man and three assistants are required to manage this machine, and two others to attend the lighters. There are 12 boats of 500 tons each employed, and the ordinary work performed is about 45 tons per hour.

DRILLING. In metal works it is frequently necessary to drill holes of various sizes, and with a greater or less degree of accuracy. The methods of drilling are very numerous, as are the forms and sizes of drills used for the purpose. Drills for piercing metal are not, however, so varied in form as those used for piercing wood, [See AUGER;] they are mostly pointed, and first make conical holes, so that while the point of the drill pursues the original line, it at length produces a cylindrical hole. Drills used with the drill-bow do not make holes exceeding ¼ inch in diameter: the edges of these drills cut when moved in either direction by the reciprocating motion of the drill-bow, their cutting edges being situated on the line of the axis, and chamfered on each side; hence they cut or scrape equally well in both directions of motion. Fig. 746, is the ordinary double-cutting drill, in which the two facets forming each edge meet at an angle of about 50° to 70°, and the two edges forming the point, meet at about 80° to 100°. The watchmakers, however, sometimes make the end of this drill as obtuse as an angle of about 120°, the object being to prevent the point from protruding through thin works much before the completion of the hole. Fig. 747, is a drill with two circular chamfers; this bores cast-iron, and even wrought-iron and steel, more rapidly than any other reciprocating drill, but a hole must be first made for it with a pointed drill. Fig. 748, is the flat-ended

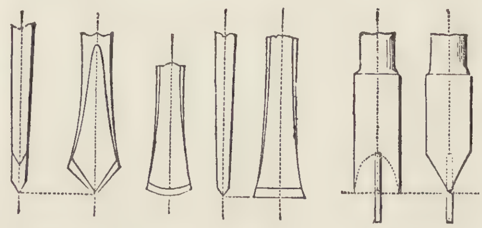


Fig. 746. *Fig.* 747. *Fig.* 748. *Fig.* 749.

drill used for flattening the bottoms of holes. Fig. 749, is a square countersink drill used for inlaying the heads of screws: it is made cylindrical, and pierced for the reception of a small central pin, and afterwards sharpened to a chisel edge as in the figure. The pin may be enlarged by having circular collars fitted on it, or such collars may be fitted on the larger part to serve as a stop in inlaying. The cutler's duplex expanding drill, Fig. 750, is described under CUTLERY.

Drills which cut only in one direction are shown in the following figures. Fig. 751, is the common single-cutting drill for the drill-bow, brace, and lathe.

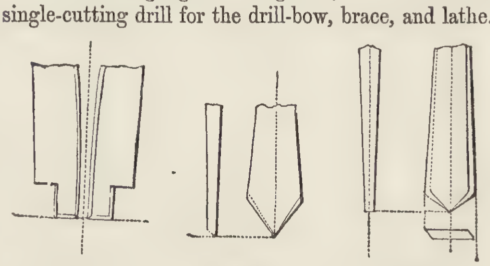


Fig. 750. *Fig.* 751. *Fig.* 752.

The point is nearly a rectangle formed by only two facets, which meet the sides at about 80° to 85°, and therefore lie nearly in contact with the extremity of the hole operated on. Turning tools for brass are formed in this way. Fig. 752, is a drill suitable for horn, and substances liable to clog the drill; the chamfers are rather more acute and are continued around the edge behind the largest diameter, so that the drill can cut its way out of the hole. The single chamfered drill, Fig. 751, cuts more quickly than the double chamfered, Fig. 752, but the former is more liable to swerve or run from its intended position. "In using the double cutting drills, it is also necessary to drill the holes at once to their full sizes, as otherwise the thin edges of these tools stick abruptly into the metal, and are liable to produce jagged and groovy surfaces which destroy the circularity of the holes: the necessity for drilling the entire hole at once, joined to the feebleness of the drill-bow, limits the size of these drills." In using the single chamfered drills, it is desirable to make large holes by a series of two or more drills; "first, the rim of the drill is in a measure proportioned to its diameter, therefore the small tool departs less from its intended path, and a central hole once obtained, it is followed

with very little after risk by the single cutting-drill, which is less penetrative. This mode likewise throws out of action the less favourable part of the drill near the point, and which in large drills is necessarily thick and obtuse: the subdivision of the work enables a comparatively small power to be used for drilling large holes, and also presents the choice of the velocity best suited to each progressive diameter operated upon."[1] Where sufficient power can be obtained, it is desirable to enlarge the holes previously made with the pointed drills by some kind of pin-drill, such as Fig. 753, in which the guide principle is employed very perfectly. Such a drill as this is used for cutting out large holes in cast-iron and other plates: the narrow cutter removes a ring of metal,

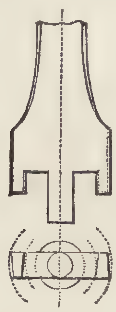


Fig. 753.

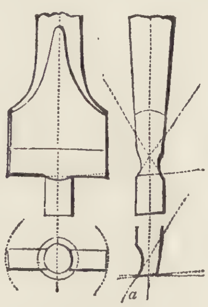


Fig. 754.

which is less laborious than cutting the whole into shavings. Fig. 754, is the ordinary pin-drill used for making countersinks for the heads of screw bolts inlaid flush with the surface. When this drill is used for iron, it is fluted: the form of one of the edges is shown at *a*.

The drills are assisted by some lubricating fluid, such as oil for most metals, or, for greater economy, soap and water; milk is used for copper, gold, and silver; but cast-iron and brass are usually drilled without lubrication. Common pointed steel drills are commonly used for the above metals and for alloys of similar degrees of hardness; but for lead and very soft alloys, carpenters' spoon bits and nose bits [See AUGER] are commonly used with water. For hardened steel and hard crystalline substances, copper or soft iron drills supplied with emery powder and oil are used; or diamond drill points [See CARBON, Fig. 465,] are used for hardened steel with oil alone. For various forms of tools used for mineral substances, see BORING.

The drill used in watch work is the smallest: it is made of a piece of steel wire tapered off at one end, flattened with the hammer and filed up in the form shown in Fig. 755: it is then hardened by heating it in the flame of a candle, and cooling it by plunging it into the tallow. The reverse end is made into a conical point and hardened: a small brass sheave is attached near this end for the line of the drill bow which may be a fine horse-hair stretched by a piece of whalebone. Fig. 755 is the watchmaker's drill on a large scale. As the drills increase in size the bow is increased also: the bow may be formed of the half of a solid cane about 1 inch in diameter at the larger end, and 30 inches long, or it may be made of steel

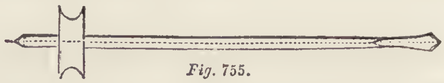


Fig. 755.

with a hook at the end for the knot or loop of the cord, and a ferrule or a ratchet, round which the spare cord is wound. The breast-plate used for the short end of the drill is shown in Cutlery, Fig. 707.

To prevent a constant repetition of the shaft and pulley, holders, or *drill-stocks*, are often used, a simple form of which is shown in Fig. 756: it has the centre and pulley of the common drill, but the opposite end

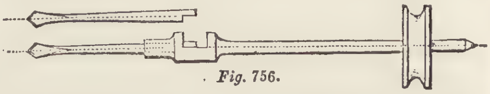


Fig. 756.

is pierced with a hole, at the inner extremity of which is a notch: the shank of the drill is made cylindrical, and a short portion is nicked down so as to slide into the gap in the drill stock, by which the drill is prevented from revolving in the stock.

The *drilling-lathe* is a miniature lathe-head, the frame of which is fixed in the table vice; the mandrel is pierced for the drills, and has a pulley for the bow, as in Fig. 756, except that it is used as a fixture. Fig. 757 is a common form of drill stock, in which the revolving spindle is fitted in a handle, so that it

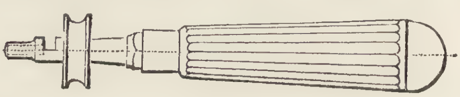


Fig. 757.

may be held in any position without the use of a breast-plate; the handle is hollowed out for receiving the drills, and is fluted to allow it to be held firmly.

The *smith's press-drill* is shown in Fig. 758. It consists of two pairs of wooden standards, between

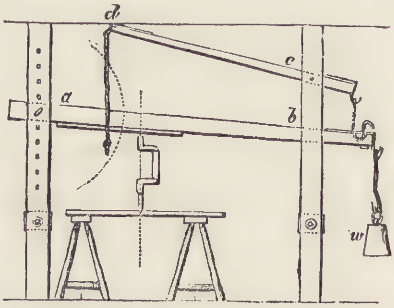


Fig. 758.

which works the beam *a b*; the pin near *a* is placed at any height, but the weight *w* remains constant, the pressure being regulated by the distance of the brace from the fulcrum *a*, and this part of the beam has an iron plate full of small centre holes for the brace. The weight is raised by the second lever *c d*, the two being united by a chain, and a chain or rope is also suspended from *d* within reach of one or two men who move the brace. When the drill is nearly through

(1) Holtzapffel: "Mechanical Manipulation," vol. i. Chapter xxiv. on Boring Tools.

the hole, the weight must be relieved, or it may suddenly break through. The defects of this machine are, that the upper point of the brace moves in an arc instead of a right line; and that there is a necessity of shifting the fulcrum *a*, and for re-adjusting the work under the drill for each different hole.

Fig. 759 is a portable iron bow frame or clamp, in which the pressure is applied by a screw. In a common form used for boring the sides of water and gas pipes the frame divides into two branches about 2 feet apart, and these terminate like hooks, which loosely embrace the pipe, so that the tool retains its position and may be used by one man; whereas in Fig. 758 one man is required to hold the frame, while another uses the tool.

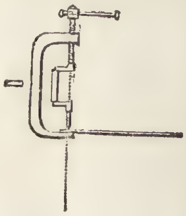


Fig. 759.

The more modern form of drilling apparatus is shown in Fig. 760. It consists of a cylindrical bar, *a*, on which the horizontal rod *b* is fitted with a socket capable of being fixed at any height or in any angular position by the set-screw *c*. A socket slides upon *b* capable of being fixed by its set-screw *d* at any distance from *a*; *e* is a long vertical screw, passing through the socket, by which the brace is thrust into the work to be drilled; this is placed level either on the ground, on trestles, on the work bench, or in the vice; the screws *c* and *d* are loosened, and the brace is put in position for work, and examined with a plumb line; the whole is then made fast by the screws *c* and *d*. In some cases the rod *a* is rectangular, and extends from the floor to the ceiling, and traverses in fixed sockets. In Fig. 760 the rod *a* terminates in a cast-iron base, by which it is grasped in a tail-vice, or it may be fixed upon the bench, in which case the nut is unscrewed, and the cast-iron plate *p* when reversed serves as a pedestal, the stem is passed through a hole in the bench, and the nut and washer when screwed on the stem beneath secure all very strongly together.

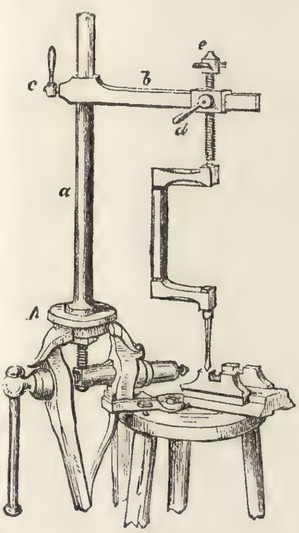


Fig. 760.

The common brace, shown in Fig. 761, is fitted with a left-hand screw. Mr. Holtzapffel remarks that "various useful drilling tools for engineering works are fitted with left-hand screws, the unwinding of which elongate the tools; so that for these instruments which supply their own pressure, it is only necessary to find a solid support for the centre. They apply very readily in drilling holes within boxes and panels, and the abutment is often similarly provided by projecting parts of the castings; or otherwise the fixed

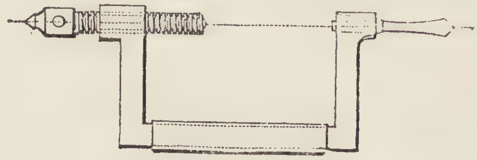


Fig. 761.

support is derived from the wall or ceiling, by aid of props arranged in the most convenient manner that presents itself. . . A right-hand screw would be unwound in the act of drilling a hole when the brace is moved round in the usual direction, which agrees with the path of a left-hand screw. The cutting motion produces no change in the length of the instrument, and the screw being held at rest for a moment during the revolution, sets in the cut; but towards the last, the feed is discontinued, as the elasticity of the brace and work suffice for the reduced pressure required when the drill is nearly through, and sometimes the screw is unwound still more to reduce it."

A simple addition to the braces and drill tools is a socket, Fig. 762, with a square hole at one end for the drills, and at the other end a square tang to fit the brace. In this way the length of the drill can be

Fig. 762.

extended for reaching deeply seated holes. These sockets are made of various lengths, and in some cases 2 or 3 are used together to extend the length of the brace to suit the position of the prop.

The drilling tools now described are driven by hand-power. In some kinds of work, however, they are fixed in square or round hole drill-chucks, which screw upon the lathe mandril. In the manufacture of harps, for example, there is a vast quantity of small drilling which is performed in this way. Various forms of lathe-drills and other forms of hand-drills are described

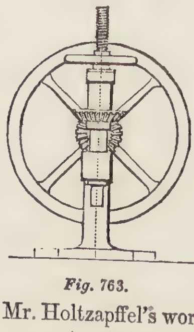


Fig. 763.

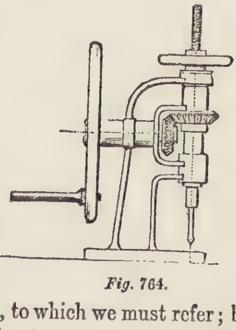


Fig. 764.

in Mr. Holtzapffel's WORK, to which we must refer; but we cannot conclude without some notice of drilling machines worked both by hand and by steam-power. Of the former kind is Nasmyth's *Portable Hand-drill*, Figs. 763, 764, in which the spindle is driven by a

pair of bevil pinions, the one attached to the axis of the vertical fly-wheel, the other to the drill-shaft, which is depressed by a screw moved by a small hand-wheel.

Messrs. Whitworth and Co., of Manchester, have constructed a drilling machine, which is one of the most complete tools of the kind ever constructed.[1] Fig. 765 is a vertical section thereof; in the plane of the axis of the driving cone and work-table. A A is a

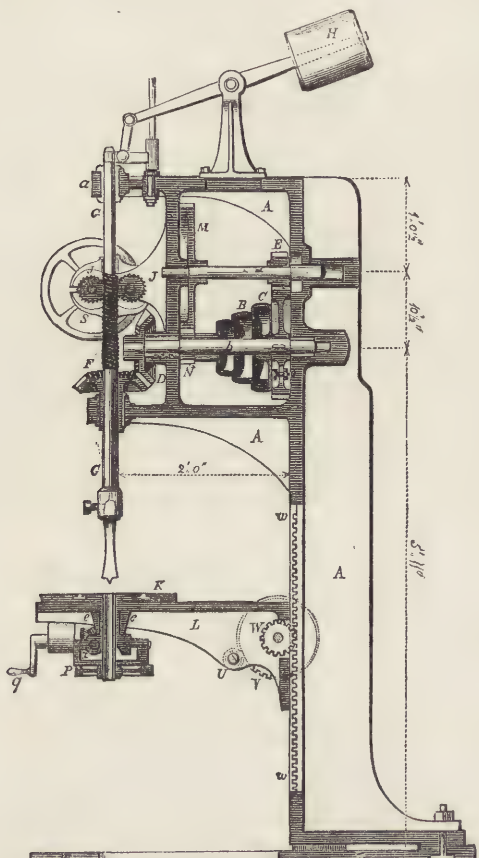


Fig. 765. WHITWORTH'S DRILLING MACHINE.

cast-iron framing, upon which the working parts are carried, as also the work-table and its motions. This framing is formed of a single casting, and is fixed by 3 strong bolts upon the sole plate T, which is intended to rest without fastening upon the floor of the work-shop. A strong bracket on the upper portion of the main frame carries the outer ends of the cone spindle *b*, and back speed spindle. Upon the spindle *b* is the driving cone B of 3 speeds, the spur-wheel C, and the bevil pinion D. The speed cone B is loose upon the shaft, and communicates motion to it only by means of the spur-wheel C, which is keyed upon the spindle, and to which the cone can be attached by a stud-pin and nut at *c*. This wheel geers with the pinion E, on the same spindle which carries the wheel M; this, in turn, geers with the pinion N, which is fast upon the end of the cone B, but runs loose upon the cone spindle *b*.

Supposing the back speed to be removed, the cone being driven by its belt causes the spindle *b* to revolve, because it is attached to the fast-wheel C, and also gives motion directly to the bevil pinion D on the end of the spindle. This again geers with the bevil wheel F on the drill spindle G G, which is free to slide vertically in the eye of the wheel, while it is prevented from revolving in it by a sunk feather. In this way 3 different degrees of quick speed may be given to the drill. But if the back speed be in geer, as in the figure, and the stud-pin *c* removed, and the cone thereby loosened from its attachment with the wheel C, the motion communicated to it will not drive the shaft *b* directly as before, but the pinion N being fast upon it will give motion to the wheel M upon the same spindle with the pinion E. This last will, therefore, make the same number of revolutions as M, but being smaller in diameter will convey a proportionally less velocity to the wheel C, with which it geers, and which it consequently drives with a speed diminished in the ratio of the geering pairs. Now the wheel C being fast on the shaft *b* conveys through it to the bevil pinion D the same diminished speed, and this again to the drill spindle G G. This reduced speed may be varied as before by placing the belt on one pulley or other of the speed cone. Behind the pinion E is a recess to allow it to enter when the back speed wheels are to be thrown out of geer; this speed geer is only required when the machine is boring holes of upwards of 1½ inch diameter. The wheel F is cast with a long hollow boss fitted into a brass collar in the lower branch of the carrying bracket. The drill spindle passes through the wheel F, which thus serves as its lower guide. The upper end of the spindle is guided in a collar similarly fitted into the upper branch of the bracket at *a*. In the figure it is shown at the lowest limit of its travel. A back weight, H, is attached to the top of the drill spindle, by a jointed lever and guide link which embraces the top of the spindle, and moves upon a vertical guide rod kept firm in its place by having its lower end held by a screw nut. The drill spindle is itself screwed towards the middle of its length, where it is embraced by 2 screw wheels, J J, between which it turns, and which serve the purpose of a nut to feed down the spindle in the operation of drilling.

K is the table upon which the article to be bored rests, and to which it can be firmly held down and adjusted by T-headed bolts and glands, the table being recessed and grooved to receive and retain the T-heads of the holding bolts. The table is supported upon the sole of the large bracket L attached to the framing A by two pieces not shown in the figure, bolted upon it and planed true to the angle of the inverted bevil edges of the broad face-rib of the main frame. These edges are also planed where they meet the oblique faces of the pieces, by which means a joint is formed which allows of a sliding motion verti-

[1] (1) The figure has been copied and the description abridged from Mr. David Scott's useful and instructive work, "The Engineer and Machinist's Assistant." 4to. Glasgow, Edinburgh, and London: 1847.

cally, but does not admit of lateral deviation. This bracket is raised and depressed by means of a hand crank applied at U. Upon this spindle is fixed the spur-pinion which geers with the spur-wheel V on the same spindle with the pinion W, which geers in turn with the rack *w* set into the frame A. By turning the hand crank on U the bracket can be raised or lowered. The table K has a double movement upon the sole of the carriage bracket: one movement is circular, and the other in the direction of the length of the table. The circular movement is effected by means of the hand crank *p* upon the spindle *y*, Fig. 766, carried in bearings formed on the box X, which thus serves as a centre of rotation. On the spindle *y* is a worm which, geering with the worm wheel P on a stud projecting downwards from the table K, conveys the motion of the handle *p* to the table. The lateral movement is effected by means of a recess in the form of a parallelogram, cast in the sole of the carriage bracket L, with projecting ribs *e e* on its under side, which form guides, against which the cover of the travelling box X slides. Motion is communicated by the handle *q* upon the spindle which carries the bevil wheel O: this spindle has its bearings attached to the bracket L, and its wheel geers with an equal wheel upon the end of the screwed spindle *d*, which has its bearings also attached to the sole plate of the carriage bracket, and works in a long nut or internal screw formed in the cover of the travelling box X. See Fig. 766. By turning the handle *q*, the piece which serves the purpose of a nut on the screw *d* is carried along in the direction of the length of the screw; but the nut being attached to the table K, the whole is moved simultaneously in that direction. By these two motions any point of the table K can be brought under the axis of the drill; and by means of the vertical motion it can be placed at any convenient height.

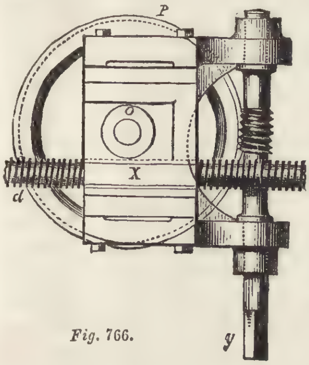


Fig. 766.

The feed of the tool is obtained by means of the two screw wheels J J, on the axis of which are two pulleys embraced on the circumference by friction collars, S S. The bearings of the axis being attached to the framing A, it is evident that the machine being in motion, if the pulleys be prevented from revolving, the wheels J J will also remain at rest; but the screwed part of the drill spindle revolving between them, they will act as a stationary nut, and cause the spindle to descend through a space equal to one thread of its screw during every revolution. If the pulleys and wheels be free, the screw of the spindle, instead of descending, will simply cause the wheels J J to revolve on their axis through a space equal to one tooth during every revolution of the screw. Between these extremes any amount of feed or downward motion of the drill-spindle may be obtained simply by retarding the motion of the wheels, by means of the friction collars S S, which embrace the small pulleys on their axis; for the friction of the collars being less than to prevent entirely the motion of the wheels, and at the same time greater than to allow a tooth to pass during a revolution of the spindle, a downward motion of the spindle must thus be produced equal to the retardation of the pulleys produced by the friction collars. The tool can be speedily withdrawn by slacking the friction collars, when the balance weight H will raise the spindle in ordinary cases; and when the tool has a hold in the hole which is being bored, the balance weight can be assisted by the hand wheel placed on the axis of one of the wheels J: the wheel and screw will thus for the time be converted into a pinion and rack.

DRUGGET, a coarse woollen fabric used for covering carpets.

DRUMMOND'S LIGHT. See LIGHT—LIME.

DRY-ROT. See TIMBER.

DUCTILITY. See ELASTICITY—METALS.

DUNG. See MANURE.

DYEING is the art of imparting to wool, silk, cotton, linen, leather, &c., colours which resist the operation of washing and the wear to which they are subject when made up into articles of furniture or clothing. This art was known at a very early period. Jacob made for Joseph a coat of many colours, (Gen. xxxvii. 3;) and in Exodus frequent mention is made of the ornaments for the Tabernacle as being composed of blue, purple, scarlet, and fine linen. We read also in 2 Chron. ii. that Solomon having sent to Tyre for coloured linens, the king of that country answered his request by sending him a man skilful to work "in purple, in blue, and in fine linen, and in crimson." Ezekiel, (593 B.C.) in his prophecy against Tyre (xxvii. 7), speaks of "blue and purple from the isles of *Elishah*," which has been supposed to refer to Elis on the west side of the Greek Peloponnesus, and hence it has been inferred that the Tyrians in the time of Ezekiel drew their supply of shell-fish used for dyeing purple from the coast of Greece. The Tyrian purple was greatly prized among the nations of antiquity. It is supposed to have been obtained from two different kinds of shell-fish, described by Pliny under the names *purpura* and *buccinum;* it was extracted from a small vessel or sac in their throats, one drop only being obtained from each animal, but an inferior colour was obtained by crushing the whole substance of the buccinum. A quantity of the juice having been collected, sea salt was added, and it was allowed to stand three days; after this, it was diluted with five times its bulk of water, kept at a moderate heat for six days more, and occasionally skimmed, and when thus clarified it was used for dyeing white wool previously prepared by the action of lime-water or of a species of lichen. For the finest Tyrian purple, the wool was first plunged into the juice of the purpura, and then into that of the buccinum; by exposure to air and light

the wool passed through various shades of citron yellow, green, azure, and red, and after 48 hours a fine purple was produced. In some cases the wool was first dyed with a cheap dye, and the woven cloth was finished with the precious juice. The colours were durable, but very costly: Pliny states that a pound weight of the double dipped Tyrian purple was sold in Rome in the time of Augustus for 100 crowns, (equal to about 30*l*. of our money.)

This enormous price did not prevent many of the citizens of Rome from wearing purple attire until the time of the emperors, when the use of purple was limited to them. This exclusiveness proved fatal to the manufacture: it languished until the eleventh century, and then became extinct. In the seventeenth century the art of dyeing purple was revived by Mr. Cole, of Bristol, and in the eighteenth century by M. Réaumur, of France; but by this time finer colours had been discovered, and cheaper processes invented.

The ancient Greeks do not seem to have attended much to the art of dyeing: the people of Athens wore woollen garments of the natural colour, and although the more luxurious Romans patronised those who cultivated the art, yet the processes of a trade or manufacture were thought to be beneath the notice of any writer capable of describing them. We learn incidentally from Pliny that the competitors in the circus were clothed in dresses of green, orange, grey, and white. The art was lost at Rome after the invasion of the northern barbarians in the fifth century; but it was practised in the East and revived in Europe about the end of the twelfth century. Florence became celebrated in the art, and in the early part of the fourteenth century numbered not less than 200 dyeing establishments.

The discovery of America supplied Europe with a variety of new colouring-matters, such as indigo, logwood, quercitron, Brazil-wood, cochineal, arnotto, &c. Before the introduction of indigo, woad was used for dyeing blue, and the cultivators of this plant in England and on the Continent endeavoured to prevent the use of indigo, which, by a decree of the German Diet in 1577, was declared to be "a pernicious, deceitful, eating, and corrosive dye." The introduction of logwood was opposed from similarly interested motives: its use was prohibited by a statute of Elizabeth, under heavy penalties, and all that which was found in the country was ordered to be destroyed: it was not until the reign of Charles II. that its use was permitted.

Such narrow prejudices as these of course interfered with the progress of the art in this country; but by degrees, valuable improvements were made, and new processes introduced from abroad, such as the method of dyeing Turkey-red,—one of the most durable of colours. It was discovered in India, and afterwards practised in other parts of Asia and in Greece. About the middle of the last century some Greek dyers established dye-works for this colour in France; and in 1765 an account of the method of producing it was published, by order of the French government. About the end of the last century the method was practised in England, when a Turkey-red dye-house was established in Manchester, by a Frenchman, who obtained a grant from Government for the disclosure of his process, which, however, was not very successful. A better process was introduced into Glasgow by a Frenchman named Papillon; but before this, Mr. Wilson of Ainsworth, near Manchester, had obtained the secret from the Greeks of Smyrna, which he made public.

The methods of imparting a permanent colour to textile fabrics are almost as numerous as the colouring matters employed. Most of the colours used in dyeing are vegetable: a few are animal and mineral. The most vivid and brilliant vegetable colours, such as those of flowers and other parts of plants exposed to the light, are small in quantity, very fugitive, and difficult to separate. The colouring matters of plants capable of being isolated, are mostly yellow, brown, and red; the only blue dyes furnished by plants are indigo and litmus; no black vegetable dye has been isolated. Most vegetable colours are soluble in water; and those which are not so can be dissolved in alcohol, ether, or the fixed oils. Vegetable colours are permanent in dry air; but they gradually fade in moist air, especially under the influence of light. The blue of most flowers is converted into red by an acid, and into green by an alkali.

Not only do the methods of dyeing vary with the nature of the dye-stuff, but also with that of the material to be dyed; different methods being adopted for cotton, silk, and wool. In order to convey a general idea of the art, we will refer principally to the dyeing of cotton, which receives colour much less easily than wool and silk, and therefore requires more numerous and elaborate processes.

The appearance of a large dye-house is very interesting from the variety and magnitude of the processes carried on therein. The following general sketch of the Egerton Dye-works at Turton, near Bolton, is quoted from the Editor's work on the "Useful Arts and Manufactures of Great Britain." [1]

"The dye-house at Turton consists of an immense apartment, which forms the basement story of a large cotton-mill. It is paved with stone, and supplied with a complete system of drainage for carrying off the spent dye-stuffs and soiled water which result from each day's operations. On entering this apartment, the visitor is struck with what appears to be the confused assemblage of differently-shaped machines, unlike the sameness which is equally remarkable in the grouping of the machinery of a spinning or weaving-mill. Here are large stone cisterns for bleaching and for washing; dash-wheels, and other wheels, also for washing; vessels containing dye-stuffs, called *dye-becks;* others, containing soap and water, called *soap-becks;* mangles for rolling the cloth; others furnished with brushes for laying the fibres all in one direction; squeezing rollers for pressing out the water from the goods; and a curious

(1) We have to acknowledge our obligations to this work in the preparation of this article, and also to Mr. Parnell's "Chemistry applied to Manufactures." 8vo. London, 1843.

machine for drying the goods by centrifugal force, which will be noticed hereafter. Under the feet are streams of all colours threading their way through the dregs of other spent dye-stuffs which had been thrown away some time before. Occasionally may be seen a vessel containing a liquid which is boiling without any visible source of heat. Heat, however, is supplied by the introduction of steam from a large boiler in a neighbouring apartment. There are also conveniences for supplying water to almost any amount. In some dye-works the daily consumption amounts to from 600,000 to 800,000 gallons. The purity of the water is of the utmost consequence; distilled or rain-water, or that of an Artesian well, is generally better than spring or river-water, which usually contains lime, and this exerts an injurious action on the dye-stuff: there is also a small quantity of iron in most spring and river-water, which gives a brown tinge to goods washed in them. Adjoining the dye-house is a room for storing, grinding, mixing, and dissolving the various dyeing materials, salts, &c. Infusions of such drugs as fustic, sumach, and logwood are made in tubs or vats; 50 lbs. of the drug being mixed with 200 gallons of boiling water. Some of the vats are furnished with a perforated false bottom, to separate the solid matter from the infusion, and the latter is conveyed to vats in the dye-house. A decoction of sumach is obtained by boiling it in an open copper boiler, which is the vessel usually employed for decoctions. For some delicate dyes, where a steam heat is applied, vessels of tinned iron or copper are used. Different vegetable colouring matters vary so much in their properties, that few general observations apply to all of them. If the substance be very soluble, its solution is usually made

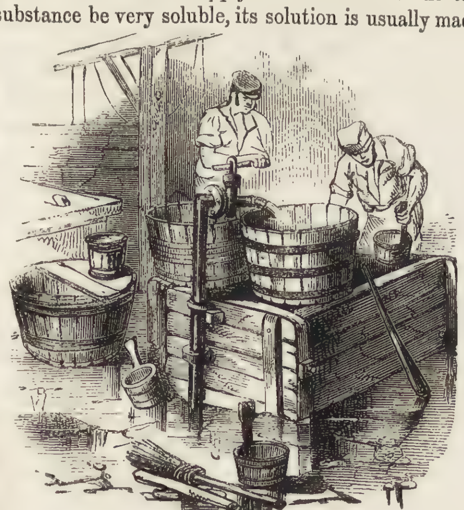


Fig. 767. LOGWOOD SAWDUST DYE-TUBS.

in cold water: if only slightly soluble, heat is applied, provided the colour is not injured thereby. When the solution is required to be highly charged with colour, a portion of the water is driven off by heat; but this requires caution, as many vegetable colours are injured by long boiling. If the goods are not kept in constant motion when in the dye-beck, the infusion should be previously filtered, or the clear part poured off, to separate insoluble woody matters. In some cases a coloured infusion is obtained by enclosing the colouring substances in bags, which are removed from the liquid when sufficient colour is imparted. If, however, the goods are kept in continual motion while in the dye-beck, as is almost always done with cottons, the separation of the insoluble matters is immaterial. The vegetable mate-

Fig. 768. DYE-BECK.

rial is commonly introduced in a state of coarse powder into the dye-beck containing cold water: the pieces of cotton are put in at the same time, and the temperature of the liquid gradually increased by the introduction of steam by a pipe connected with the boiler. Motion is given to the goods in the dye-beck by a winch or reel placed horizontally over the middle, so that the cloth may be made to descend into either compartment of the dye-beck by the rotation of the wheel. By another arrangement, shown in Fig. 768, the cloth is wound from one roller to another, passing in the interval through the dye, under a roller placed at the bottom of the dye-beck."

The fibres of vegetable and animal substances receive colour more readily before they are spun into yarn, and the yarn admits of being more readily dyed than the woven cloth, because the solution of colouring matter has more difficulty in penetrating the twisted than the open fibres. Thus wool in flocks, after having been washed in an alkali and bleached, takes more colour than when it is spun or woven; and the colour of the interior of a piece of thick woollen cloth, dyed in the piece, is often less intense to the eye than the colour of the exterior. Dyeing in the piece is, however, less expensive than dyeing wool in flocks or in yarn, because less of the material is wasted, and the colour is not exposed to injury during the processes of spinning and weaving.

In dyeing cotton goods, several pieces are usually joined together, to make a length of from 100 to 120 yards. Several processes preparatory to the dyeing are required. The goods are first scoured,

and in some cases boiled in sour water or in alkaline ley, for about two hours, then wrung out, and rinsed in a stream of water until the water comes off clear. The sour water is prepared by the addition of $\frac{1}{50}$th part of sulphuric acid, and when the stuffs are steeped in it, the acid combines with the calcareous earth and iron contained in the fabric, the presence of which would interfere with the full effect of the colouring matter.

In the dyeing of cotton aluming is an important preliminary process. 40 or 50 lbs. of alum previously dissolved in warm water are mixed in a vat with 40 or 50 pailfuls of water, the mixture being carefully stirred to prevent the salt from crystallizing. Each pound of cotton stuff requires 4 oz. of alum. Some dyers use a quantity of soda equal to about $\frac{1}{16}$th of the alum; others add a little tartar and arsenic. The threads of the fabric are impregnated by working them

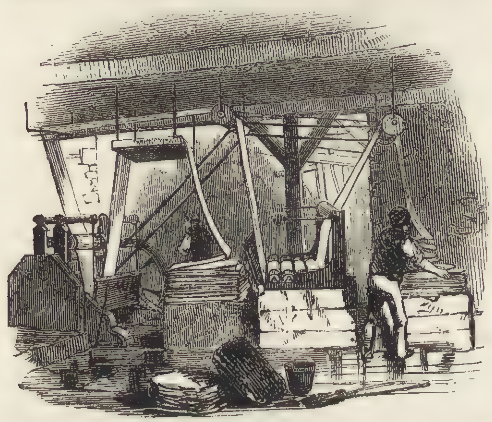


Fig. 769. ALUM CISTERN.

in small quantities of this solution. After this has been done some time, the whole of the liquor is added, and it is left for 24 hours, after which it is washed in running water for $1\frac{1}{2}$ or 2 hours. Cotton gains by aluming about $\frac{1}{40}$th part of its weight.

Galling is another preparatory process. Powdered

Fig. 770. PREPARING CISTERN.

galls are boiled for two hours in water, the quantity of which must be regulated by the quantity of thread to be galled and the amount of the effect required. When the solution has cooled down, it is divided into a number of equal parts, in order that the thread may be wrought pound by pound. The whole stuff is then put into a vessel, and the remaining liquid poured upon it. It is left for 24 hours if it is to be dyed black, but for other colours 12 or 15 hours suffice. It is then wrung out and dried.

In passing the goods through these preparing cisterns, the effect desired is produced more effectually and in quicker time, by allowing the cloth to unwind gradually from a roller, and after going through the liquid in a regular manner under a roller at the bottom of the vessel, to pass between two rollers on coming up out of the liquid, whereby the superfluous moisture is pressed out of the cloth and it is again prepared for another dipping. Some idea of the arrangements adopted will be gained from an examination of the Figures.

It is not possible in this short notice to attempt more than to convey a general notion of the chemical principles upon which the art of dyeing depends. In producing certain results, advantage is taken of that affinity or attraction by which one substance A unites with another substance B in preference to a substance C; so that if C be dissolved in A, the addition of B would cause C to leave A in order to unite with B; as when resin is dissolved in spirits of wine the addition of water will throw down the resin as a precipitate, because the spirit has a stronger affinity for the water than it has for the resin. Other cases of simple and double decomposition are given in the article AFFINITY, to which we must refer, especially to the diagrams at page 22, because one of the simplest methods of dyeing depends on such a case of double decomposition as is there given. The colouring matter is produced in or upon the cloth in the form of an insoluble precipitate by mixing two solutions, in neither of which does the colour exist separately. The advantage of this method is, that the cloth can be impregnated with one solution, and then, upon immersing it in the other, the insoluble colouring matter is formed within the elongated cell or tube which forms the fibre of the cloth, so that the resulting precipitate being, as it were, imprisoned within the fibre, is rendered incapable of being removed by washing. In this way mineral colours, such as chrome-yellow, prussian-blue, iron-buff, and manganese brown, may be applied to textile fabrics. In all these cases the proper colouring matter is insoluble in water, and is precipitated whenever the two solutions proper for its formation are mixed. Thus, when an aqueous solution of bichromate of potash is mixed with an aqueous solution of acetate of lead, an insoluble precipitate of chromate of lead (chrome-yellow) is produced. In the processes for dyeing cloth with mineral colours, the fastness of the colours is supposed to be entirely a mechanical effect, in no way referable to a chemical attraction of the fibre for the colouring matter. A piece of white cotton cloth moistened with either a solution of bichromate of potash or of acetate of lead may be easily cleared of either of these salts by washing it in water; but if the cloth be first

impregnated with one solution, and afterwards with the other, the precipitate of chrome-yellow produced within the fibre can never be removed by washing with water. The chrome-yellow that is afterwards washed away is merely attached loosely to the exterior of the fibre.

A second method of dyeing is with a *mordant;* this is usually a metallic salt, which has an affinity for the tissue, as well as for the colouring matter in solution; forming with the latter an insoluble compound.[1] This method of dyeing is useful for all those vegetable and animal colouring matters which are soluble in water, but have not a strong affinity for tissues. The action of the mordant is to withdraw them from solution, and to form with them, upon the cloth itself, certain compounds which are insoluble in water.

In dyeing cotton with a mordant, it is generally necessary that the mordant be produced on the cloth in a form insoluble in water; but in order that it may penetrate to the interior of the cloth about to be dyed, it must first be applied in a state of solution. The excess of mordant is then removed;[2] for, if allowed to remain, the dye would be formed chiefly on the surface, and only a small quantity would penetrate the fibre. But when the surplus mordant has been removed, and the cloth passed through the dye-beck, the resulting colour is often dull and liable to change, apparently because the quantity of mordant is too small to combine with all the colouring matter which is deposited. But on applying the same or some other mordant a second time, the colour is greatly improved in lustre, and becomes permanently attached. This second mordant is called an *alterant.* Thus, if a piece of white cotton be removed at once from a dilute solution of perchloride of tin to a weak decoction of logwood, the cloth assumes an uneven violet colour, which can be removed by washing. But if the perchloride be removed from the surface of the cloth before it is put into the decoction, the piece assumes a dull, brownish, violet tint. If a small quantity of acetate of alumina be then added to the liquor as an alterant, the cloth acquires a good permanent violet or purple colour.

When the surplus mordant has been removed, the sooner the goods are exposed to the dye-stuff, the better in general is the colour they assume.

When the dye-stuff is insoluble in water, a third method of dyeing is adopted. In such case, the mordant may be dispensed with; but it is necessary to make such a solution of the colouring substance as will allow it to be precipitated, in its insoluble state, when a cloth impregnated with the solution is exposed to some chemical agent.

The most important insoluble vegetable colours are indigo, safflower, and arnotto, and some yellow and brown dyes. To bring these into a state of solution, it is necessary to employ some other solvent than pure water. By exposing indigo to the action of some body which robs it of oxygen, it is brought to the state of *white indigo*, or *indigotin*,[3] which is soluble in water, if lime or some other alkali be present. If a piece of cloth be dipped in such a solution, it becomes impregnated with white indigo, and on exposing the cloth to the air it imbibes oxygen, by which it becomes converted into its original insoluble blue. This remains firmly attached to the fibre, and cannot be removed by washing in water. The calico to be dyed is stretched in perpendicular folds on rectangular wooden frames, as shown in Fig. 417, p. 284. The solution of indigo is contained in stone cisterns or vats, the tops of which are on a level with the ground. In preparing a new vat, fifty pounds of indigo are reduced to an impalpable powder, by grinding with water during ten or fourteen days. This powder is then mixed with hot water, and the requisite quantity of lime added, after which a solution of sulphate of iron is stirred in. Sulphate of iron consists of the protoxide of that metal dissolved in sulphuric acid: this protoxide converts the blue indigo into white indigo, which the presence of the lime enables the water to dissolve.

In the blue-dye-house at the print-works of Mr. Lees, of Manchester, visited by the writer, a man and a boy have the charge of ten vats. The calico being properly stretched, the frame is lowered into a nearly spent vat, and allowed to remain $7\frac{1}{2}$ minutes; it is then taken out, and left to drain for the same length of time, during which it becomes of a green colour; the frame is then turned over and immersed in the second vat, which contains a little more indigotin than the first; after remaining in this during $7\frac{1}{2}$ minutes, it is taken out and exposed to the air for another $7\frac{1}{2}$ minutes; it is treated in this way up to the tenth vat, which contains the largest amount of dyeing material. On being removed from this, it is of a deep blue colour.

The colouring matters of arnotto and safflower are scarcely soluble in water; but they dissolve readily in alkaline liquors, from which they may be precipitated by an acid. A piece of cloth being impregnated with an alkaline infusion of the dye stuff, is readily dyed by passing it through a weak acid. In practice, however, it is found desirable to add the acid to the alkaline infusion of the dye stuff, so as nearly to neutralize it; by this means the colouring matter is held in a state of feeble suspension, and readily attaches itself to the surface of the cloth.

The last method of dyeing which requires to be noticed in this place, is practised only on goods formed of animal tissue. By this method, which is called *mandarining*, an orange colour is given to silk and

(1) Some details respecting mordants are given in the article CALICO PRINTING, *ante*, p. 281.

(2) The superfluous mordant is removed from the surface of the cloth by passing the dried goods through a warm mixture of cow-dung and water, or of dung-substitute, as explained in CALICO PRINTING, *ante*, p. 281. In a few dyeing processes, instead of dunging, the cloth is winced in a mixture of chalk and sise, with hot water; the chalk serving to fix the mordant by withdrawing the small quantity of acid remaining in it. In some cases, also, instead of dunging, *branning* is used; that is, wincing the goods in a mixture of bran and hot water.

(3) White indigo is called *indigogen* by Liebig, who regards blue indigo as the oxide. Dumas considers white indigo not as deoxidised blue indigo, but blue indigo combined with hydrogen.

wool, not from the solution of a colouring matter, but by producing a certain change in the fibre by the action of dilute nitric acid. The orange colour is formed by the decomposition of a portion of the silk or wool by means of the acid.

When the cloth is removed from the dye-beck, it is submitted to several finishing processes, which vary according to the method of dyeing and the nature of the stuff. It is first carefully washed in water, to separate the coloured liquid which is mechanically attached to the cloth. It is usually dried at common temperatures, but occasionally in a well ventilated apartment, heated by steam pipes. Delicate colours are always dried in the shade.

A general idea of these finishing processes may be obtained from a notice of the treatment of cotton goods, after having been dyed with a vegetable infusion, with the intervention of a mordant.

As soon as the cloth is removed from the dye-beck, it is washed in two stone cisterns of cold water, each surmounted by a reel. It is next washed at a dashwheel; or if the action of this machine be too energetic, the *rinsing* or *washing machine*, Figs. 413, 415, page 282 *ante*, is used. The cloth still retains an excess of colouring matter, which cannot be removed by cold water: it is therefore next rinsed in a mixture of bran and boiling water, or in soap and water. This *clearing*, as it is called, is also in some cases performed by putting the cloth for a few minutes into a solution of chloride of lime.

After the clearing, all the water is expelled by squeezing rollers, or by a rotatory apparatus called the *water extractor*. The wet cloth is put into a compartment between two cylinders, and the apparatus made to perform 900 or 1,000 revolutions per minute; the water is driven out by the centrifugal force through the perforations in the cylinder, whence it flows away by a gutter or drain, and in a few minutes the cloth is nearly dry.

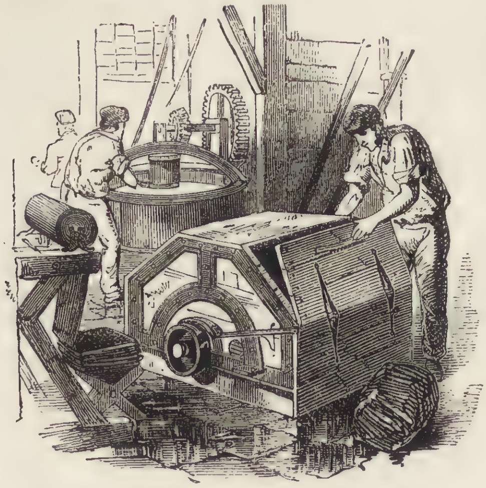


Fig. 771. WATER EXTRACTOR.

The cloth is next folded evenly, and passed, in a length of ten pieces, through the starching mangle; then through a steam drying machine, which consists of several hollow copper cylinders, each about 20 inches in diameter and 3 feet in length, filled with steam. Then comes the process of calendering, which has been already described under that head.

DYKE. Dykes or embankments form an ancient mode of defence in time of war, and examples of such earthen outworks are still to be found throughout England, either surrounding the site of old castles or fortresses, or forming a long and continuous boundary, marking the ancient division of counties. The most remarkable dykes at the present day are those of Holland, employed as a means of defence against the sea, which is ever threatening to overwhelm that extraordinary country. The greater part of Holland is below the sea-level, and consists, in fact, of land gained from the sea. Old historians speak of it as in the beginning no other than a sand-bank or more high place than ordinary, over which the tides usually flowed. This accumulation of sand checked the waters of the Rhine, and formed a bank against them, so that the mud brought down by that rapid river settled on the shores, and after long and frequent inundations produced pastures. Nature thus inviting, industrious hands were soon found, to heap up the sand seawards, and to keep as much as possible of the soil thus gained. But this soil was liable to frequent inundations, and thus a great loss of life and property occurred to those who had laboured to snatch a home from the very grasp of the waves. The history of one province in particular (Friesland) abounds with these fearful details. But the inhabitants, with wonderful tenacity, clung to their territory, and built up as fast as the sea pulled down their dykes and entrenchments. The province was inundated in the sixth and eighth centuries, and twice in the ninth century. In the twelfth century there were two inundations, and in the thirteenth there were no fewer than nine of these fearful visitations, and several of them caused important changes in the features of the country: for instance, by that of 1237 the island of Vlieland was formed; that of 1277 gave rise to the Gulf of Dollart, and swept away forty-four villages; and that of 1287 caused the Zuider Zee to assume its present extent and shape, while 80,000 persons lost their lives in the inundation. A repetition of such calamities occurred during the three succeeding centuries, until, in the sixteenth century, after a severe visitation, which swept away in different parts of Holland about a hundred thousand people, an improved method of constructing the dykes, first attempted at the beginning of that century, was more generally practised, and a law passed to enforce the keeping of them up by the owners of the land. Very strong embankments were formed, of timber filled in with large stones, and covered with earth. The dykes were raised in some places thirty feet above the ordinary level of the country, with sufficient width at the top to form a roadway. Towards the end of the sixteenth century, the practice came into use of covering the side of the dyke seawards with a layer of flags and reeds: these were twisted together in bundles, laid horizontally at the distance

of three or four yards from each other, and secured to the ground by stakes. This has been found remarkably successful in retaining the earth of the dyke in its proper place, and breaking the force of the waves. These flags are continued both above and below the main action of the water, and surmounting the whole are piles driven into the dyke, and having numbers attached to them, which are referred to by the engineers charged with the maintenance of the banks. Such are the preparations seaward: towards the land, also, the dyke is well and strongly supported with piles and planking filled in with stones, and covered with earth and turf. Of course this method of forming a dyke is not the invariable one: another is thus given in Murray's Handbook:—"The first thing necessary in the construction of these bulwarks is to secure a firm solid foundation, sufficiently strong to support the immense weight to be laid upon it, by ramming down the soil, and by laying a substratum of clay, or by driving in piles, when it is incoherent. Were the foundations weak and porous, the water would dissolve and undermine it, and the dykes sink down into a hollow. The rampart is composed as far as possible of clay: whenever that material is difficult to procure, the face of the dyke is made of clay, and the interior of earth, sand, and clay; but clay alone is preferred, as being waterproof. The face of the dyke at the water-side is made very sloping; in river-dykes generally rising one foot in four or six, and in the great sea-dyke of Cappel still more gradually, as one foot in thirteen: it is protected, or in a manner thatched, by willow-twigs, interwoven so as to form a sort of wicker-work, and the interstices are filled up with clay, puddled, to render it compact. This wicker-work is renewed every three or four years, occasioning a considerable consumption of willow-boughs; and the willow-tree is cultivated to a great extent for this purpose. The dykes are frequently planted with trees, as their spreading and interlacing roots assist greatly in binding the earth together. The base is often faced with masonry, and protected by vast heaps of stones brought from a distance, and by rows of piles driven into the ground to form breakwaters to the fury of the waves. The upper part is covered with turf, and rises sometimes to the height of 40 feet. . . . The most stupendous of these embankments are the Dykes of the Helder, and of West Cappel, at the western extremity of the island of Walcheren. The annual expense of keeping in order each of them alone amounts to 75,900 guilders (about 6,400*l.*); while the sum total annually expended throughout Holland in the repair of dykes and regulation of water-levels varies from 5,000,000 to 7,000,000 guilders (nearly 600,000*l.*)."

A scientific corps of engineers is constantly and wholly employed in watching the state of the waters and guarding against accidents. In winter these officers especially watch the most dangerous spots, erecting there the necessary magazines containing stores and implements, so as to be ready at a moment's warning. Watchmen patrol the threatened line of attack day and night, and on the slightest symptom of weakness, all hands are employed to strengthen the rampart which alone stands between their country and destruction. "It may easily be imagined," says the writer already quoted, "with what intense anxiety the rising tide is at such times observed. The accumulation of waters in the ocean causes them to ascend far above the ordinary high-water mark; and if they only surmount the top of the dyke so as to flow over it, its ruin is inevitable. When such a calamity is anticipated, the alarm-bell is rung, and every man hastens to his post. With the utmost rapidity an upper rampart is constructed upon the top of the dyke to keep out the waters. It is incredible in how short a time a bulwark of this kind is elevated: it is a race between the tide and the embankment. If the strength and solidity of the dyke be doubtful, and a breach be apprehended, large sheets of sailcloth, or mats of woven straw and rushes, are laid on the outside, in the same manner as a leak is sometimes stopped in a ship. This prevents the earth's being washed away by the action of the waves. It must be remembered that the works raised on such an emergency, vast as they are, are only temporary, and are removed whenever the danger is past. Instances are not rare in which these precautions have proved quite ineffectual, and whole districts have been overwhelmed and lost for ever in the sea, or in the Rhine and its branches."

In the course of railway operations, dykes or embankments are formed on a large scale, and in many instances with great skill and caution. The details of these belong to the vast system of which they form a part, and must therefore be considered elsewhere. See RAILWAY.

DYNAMOMETER, (from δύναμις, strength, and μέτρον, a measure,) an instrument for ascertaining the relative strength of men and animals. Some valuable information might be acquired if we had the means of ascertaining easily the relative strength of an individual at different periods of life, and in different states of health. In an instrument intended to fulfil this object, invented by Mr. Grahame, and improved by Dr. Desaguliers, a steel-yard was mounted in a wooden frame, and the strength of an individual was measured by acting on the short end of the lever, so as to produce equilibrium, the position of the weight on the long arm serving as a measure. Another instrument by Leroy, consisted of a metal tube 10 or 12 inches in length, placed vertically on a foot like that of a candlestick, and containing in the inside a spiral spring, having above it a graduated shank terminating in a globe. This shank together with the spring, sank into the tube in proportion to the weight acting upon it, and thus pointed out in degrees the strength of the person who pressed on the ball with his hand"

A better instrument than either of the above, was contrived by M. Regnier, and described by him in the second volume of the Journal de l'Ecole Polytechnique. It appears that the celebrated naturalists Buffon and Guéneau desired to have an instrument

for ascertaining the muscular force of a finger or of a hand, and also for estimating that of each limb separately, and of all parts of the body. Regnier's instrument does not satisfy all these conditions; the inventor admits that in the course of his experiments he had reason to be convinced that the construction of the instrument was not so easy as might have been expected. But, he says, "in addition to the use which an enlightened naturalist might make of this machine, it was possible to apply it to many other purposes. For example, it may be employed with advantage to determine the strength of draught cattle; and above all, to try that of horses, and compare it with the strength of other animals. It may serve to make known how far the assistance of well constructed wheels may favour the movement of a carriage, and what is its *vis inertiæ* in proportion to the load. We might appreciate by it what resistance the slope of a mountain opposes to a carriage, and be able to judge whether a carriage is sufficiently loaded in proportion to the number of horses that are to be yoked to it. In the arts, it may be applied to machines of which we wish to ascertain the resistance, and when we are desirous to calculate the moving force that ought to be adapted to them. It may serve also as a Roman balance to weigh burdens. In short, nothing would be more easy than to convert it into an anemometer to discover the absolute force of the wind, by fitting it to a frame of a determined size, filled up with waxed cloth; and it would not be impossible to ascertain by this machine the recoil of fire-arms, and consequently the strength of gunpowder."

This instrument is shown in Fig. 772. It consists

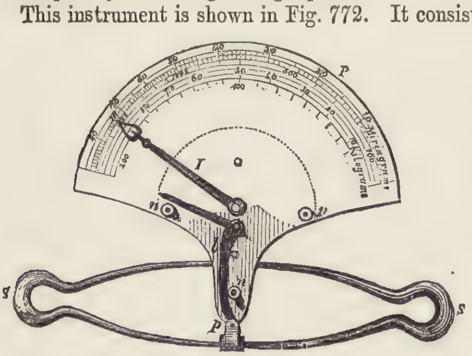


Fig. 772.

of a steel spring s s, 12 inches long, bent into the form of an ellipsis, and covered with leather to guard the fingers when it is being strongly pressed by the hands. A semicircular plate of brass P for receiving

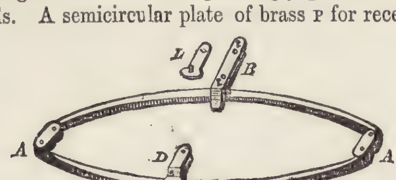


Fig. 773.

the scales or graduated arcs is fastened to the spring by means of a piece of steel B, Fig. 773, which is attached by a claw and screws. The outer graduated arc is divided into myriogrammes, and the other into kilogrammes; each arc is still further subdivided by points which express the weight in pounds *marc;* and the various parts of the scale are determined by hanging known weights to one of the extremities of the spring. On the other branch of the spring is a small steel support D, furnished with a cleft at its upper extremity for receiving freely a small copper lever E, which is kept in its place by a steel pin *p*, Fig. 774, which shows this part of the machine

Fig. 774.

on an enlarged scale. In the centre of the semicircular plate P, Fig. 772, a light steel index I is fixed upon its axis by a screw, and has a double point for indicating the divisions on both scales. A small piece of leather or cloth is glued upon the lower side of the circular part P, to render uniform and diminish the friction on the plate. The upper point of the index and the scale of myriogrammes is used in all experiments in which the spring is to be pulled in the direction of its greater axis s s, and the lower point of the index and the scale of kilogrammes is used when it is employed for experiments in which the two sides of the spring are to be compressed. This mechanism is covered with a small brass plate, Fig. 775, resting upon small cylindrical pillars *n n n*, Fig. 772, and fixed by thumb-screws. Upon this small plate is a divided arc corresponding with the first arc of the machine, and by the play of a small index *b*, Fig. 774, under the plate, the movements of the spring may be ascertained. The aperture O admits a turnscrew for the purpose of relieving or tightening the index when required. L, Fig. 773, is a brass pallet with a screw and cap, in which the lower pivot of the lever that pushes round the index plays. It acts like a spring, and yielding to any sudden concussion, prevents the mechanism from being deranged. C, Fig. 775, is a socket riveted on the small plate, in which the upper pivot of the lever turns.

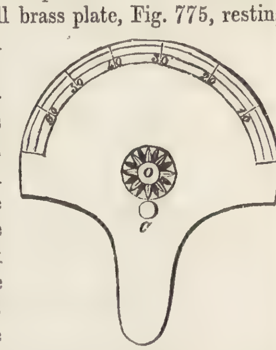


Fig. 775.

In trying the strength of the human body by means of this instrument, an iron rack is provided, on the lower part of which the feet of the person must rest, and holding in his hands a double handle of wood, as shown in Fig. 776, he exerts the strength of the reins of his body to compress or flatten the ellipse, the amount of force exerted being indicated by the index. The pin *d*, Fig. 774, pushes forward the index, which always remains at the place to which it is brought. Fig. 777, shows the method of determining the strength of the hands or the muscular force of the arms. The person lays hold

of the two sides of the spring nearest to the centre, so that his arms may be a little stretched and inclined downwards at an angle of nearly 45°. Regnier considers this position to be the most natural, and that in which a man can exert his whole force.

Fig. 776.

Fig. 777.

The index will then point out on the scale of kilogrammes, the force which has been exerted. If the strength of each hand be exerted separately, the sum of the two will be found equal to that of both exerted together. To ascertain the strength of animals, the dynamometer is applied as shown in Fig. 778. The animal is yoked to the chains C C,

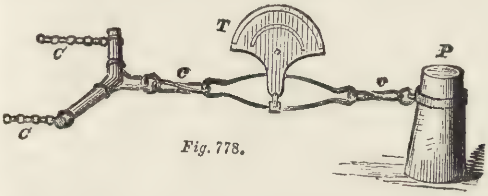


Fig. 778.

and the force which it exerts against the fixed obstacle P, is shown by the sides. The following results were obtained by M. Regnier with four good horses:—

		Myriogrammes.
Force exerted by the first	. . . . . .	36
" "	second	$38\frac{1}{2}$
" "	third	$26\frac{1}{2}$
" "	fourth	43
		4) 144
Mean result		36

which is equal to 736 pounds marc.

This instrument does not weigh more than $2\frac{1}{2}$ lbs.; but it is liable to a defect to which all springs are more or less subject; its elasticity diminishes in the course of time, and consequently the scale becomes deranged.

Other forms of dynamometer are shown in Figs. 779, 780, and 781.

Fig. 779 is formed of a band of steel bent in the middle, so as to have a certain degree of flexibility. To the expanded extremity of each limb is fixed an arc of iron, which passes freely through an opening in the other limb, and terminates outside in a ring or a hook. One of these arcs is graduated, and represents in pounds the force required to bring the two limbs nearer together. Thus, if a horse were pulling a rope attached to a body which he had to move, we may imagine the rope to be severed at a certain point, and the two ends attached to the ends of the arcs, as in Fig. 779. The force of traction exerted by the animal would be seen by the greater or less bringing together of the extremities of the instrument.

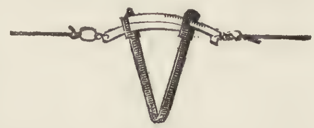


Fig. 779.

In Fig. 780, the force is measured by the collapsing of a spiral spring contained within a cylindrical case. A metal rod, occupying the axis of the cylinder, terminates at its lower extremity in a disc of metal, to which one extremity of the spring is attached. At the other end of this rod is a ring for suspending the instrument. The upper end of the spring rests against the interior of the cylinder at the top, so that when this instrument is suspended, and a weight hung on the hook at the bottom, the rod is drawn out by the collapsing of the spring; and by applying different weights the rod can in this way be graduated.

Fig. 780.

The dynamometer, Fig. 781, invented by M. Poncelet, resembles Regnier's, already described. It consists of two steel springs, connected at the extremities by a kind of hinge. The upper spring is furnished with an eye for suspending the instrument, and the lower spring with a hook for attaching a weight. The greater the weight, the greater the distance to which the two springs separate; and in this way forces are measured, by a contrivance similar to that of Regnier's instrument.

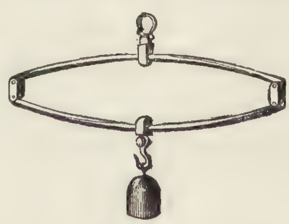


Fig. 781.

EARTHENWARE. See Pottery.

EARTHS. This term was applied by the old chemists to certain substances which were supposed to be elementary, but are now known to be compounds of oxygen and a base; they are mostly metallic oxides, such as alumina, which is an oxide of aluminum; barytes, of barium; glucina, of glucinum; lime, of calcium; magnesia, of magnesium; silica, of silicium; strontia, of strontium; yttria, of yttrium; zirconia, of zirconium.

EAU-DE-COLOGNE is a solution of certain essential oils in alcohol. It is rendered turbid by water, which combines with the alcohol and liberates the oil. This delicious scent is manufactured at Cologne. There are 24 manufacturers in the city, several of whom bear the name of the original inventor, Jean

Marie Farina. Several millions of bottles are annually exported. The manufacture is kept secret, and a great deal of that which is sold is spurious. It is difficult to procure it genuine in England, and it is not easy by external signs to detect the spurious article: for the bottle, the seal, the description, the signature of Farina's name, the paper, and the print, are all imitated to perfection; the only failure is the *eau* itself, for we have never seen that successfully imitated. A German writer says that in order to distinguish the genuine from the spurious, rub a few drops on the hand, and the genuine eau will not smell of any spirituous liquor, or of musk, or of any foreign substance, but only of the ethereal odour proper to the water. Many recipes for its manufacture have been published, but we have no faith in any of them. The following are from Lebeaud's treatise, referred to in our article on DISTILLATION:—

Dried tops of balm-mint (*melissa hortensis*)...	1 ounce.
Ditto marjoram	1 ,,
Ditto thyme	1 ,,
Ditto rosemary	1 ,,
Ditto hyssop	1 ,,
Ditto wormwood	1 ,,
Lavender flowers	2 ounces.
Angelica root	1 ounce.
Cardamon seeds	2 ounces.
Dry juniper berries	1 ounce.
Annis, cumin, fennel and carraway seeds, of each	1 ,,
Cinnamon	1 ,,
Bruised nutmegs	2 ounces.
Cloves	1 ounce.
Fresh orange peel	1 ,,
Essential oil of bergamot	1 ,,
Proof spirit of wine	10 quarts.

Digest for some days, and then distil to dryness at a water-bath.

ANOTHER RECIPE.

Proof spirit	10 quarts.
Tincture of balm-mint	1 quart.
Ditto rosemary	1 ,,
Essential oil of cedrat	2 ounces.
Ditto bergamot	,,
Ditto citron	,,
Ditto rosemary	,,
Oil of orange flowers	1 dram.

Distil at a water-bath until nothing comes over. A better eau-de-Cologne may be prepared by adding to the above:—

Essential oil of cloves	1 dram.
Essence of roses	2 ounces.
Ditto jasmin	2 ,,

These ingredients are not always distilled; but the whole are left to macerate with occasional stirring, and the clear water is then bottled.

EBULLITION. (Latin *ebullio*, to boil.) When vapour is formed from the surface only of a liquid, the process is termed EVAPORATION; but when the vapour forms and escapes from all points of the liquid mass, the process is called *boiling* or *ebullition*. The temperature at which vapour rises with sufficient force to produce ebullition is termed the *boiling point*, and the heat required to produce it varies with the nature of the fluid. Thus sulphuric ether boils at 96°, alcohol at 176°, pure water at 212°; oil of turpentine 316°, mercury 662°. The boiling point of the same liquid is constant under the same conditions, but is liable to be affected by a variety of circumstances, which will be noticed presently.

When heat is applied to the bottom of a vessel containing a liquid such as water, there is a continual displacement of the liquid particles: those near the bottom are first heated, expand, and thus becoming specifically lighter than the other particles, ascend; colder particles occupy their place, and becoming heated ascend in their turn; and thus a current is established, in which the heated particles rise up through the centre, and colder particles descend at the sides, as shown by the direction of the arrows in Fig. 782. By continuing the process the liquid particles are not only displaced, but converted into steam. If the process be carried on in a glass vessel it can be watched from the commencement, especially if the liquid contain some powder insoluble in water and of nearly the same sp. gr.: amber powder fulfils this condition; the particles of the powder follow in the course of the liquid currents. As the process continues, bubbles of vapour form on the heated sides of the vessel, rise in consequence of their levity, and burst at or near the surface. These bubbles are small in size when they first appear, but they increase in ascending; those which proceed from the hottest part of the vessel or that in immediate contact with the fire, succeed each other with the greatest rapidity. Now in order that these bubbles may form in the midst of the liquid mass which presses upon them in all directions, and ascend through it, it is evidently necessary that the steam or vapour of which they are composed should have a tension or elasticity at least equal to the surrounding pressure. It is this condition which determines the boiling points of different liquids, and also the boiling points of the same liquid under different pressures. Hence, the first condition of ebullition is, that the temperature be sufficiently high to impart to the vapour such an amount of elastic force as will enable it to overcome the pressures to which it is subject, not only from the liquid, but also from the atmosphere which presses upon the liquid. The second condition is, that such an amount of heat be present as to allow the vapour to absorb and render latent that quantity which is necessary to its existence at the temperature required. From the first condition it follows, that whatever causes the pressure on the liquid, or the elasticity of the vapour, to vary, changes also the boiling point; and from the second condition it follows, that the rapidity of ebullition, or, in other words, the conversion of the liquid into steam, depends on the quantity of heat supplied to the liquid in a given time.

Fig. 782.

The boiling point of the same liquid is liable to change from several causes, which are themselves

subject to considerable variation: viz. 1, the pressure exerted on the surface of the liquid; 2, the cohesion of the particles of the liquid; 3, the nature of the vessel containing the liquid; 4, the depth of the liquid mass; 5, the substances which the liquid may hold in solution.

1. Under ordinary circumstances, every liquid which is set to boil is under the atmospheric pressure of about 15 lbs. on the square inch [see AIR], and the elasticity of the vapour must be, at least, equal to this, before it can form and escape from all parts of the liquid. As the atmospheric pressure is itself liable to variation, not only at the same place, but on ascending any height, so the boiling point of a liquid is also subject to corresponding variations. At the level of the sea and under the ordinary pressure of 30 inches as indicated by the BAROMETER, water boils at 212° Fahr.; but on the summit of Mount Blanc, Saussure found that water boiled at 187°. At this temperature water, although boiling, is not sufficiently hot for the purposes of cooking food, and instances have occurred in high mountain regions, of its being impossible to boil an egg because the water was not hot enough to coagulate the albumen. Mr. Darwin relates that during an expedition to the high land in South America, the sailors were not able to cook some potatoes by boiling, a fact which they attributed to the circumstance of their having brought out a new tin pot for the purpose, which in some way or other was thought to be defective. Arch deacon Wollaston invented an apparatus, (or rather perfected an invention of Fahrenheit and Cavallo,) for measuring heights by the temperature of boiling water. It consisted of a mercurial thermometer with a very large bulb, dipping into a small portable boiler which was heated by a spirit lamp. Each degree of the scale occupied the space of about an inch, and by means of a vernier the 1,000th part of a degree could be read off. It was found that a difference of barometric pressure of 0.589 inches was equivalent to 1° in the boiling point, or 530 feet of ascent: and that the difference of the height of a common table from the ground would produce a difference in the boiling point, which was pointed out by the instrument.

As by diminishing the pressure we lower the boiling point, so, by increasing the pressure, the boiling point becomes raised. In a diving-bell, or at the bottom of a mine, water boils at a higher temperature, and is consequently hotter than at the surface, because the steam, having a greater resistance to overcome, must acquire a greater elasticity, and for this purpose it must take up a larger supply of heat. When the elasticity of the vapour of a liquid is known, its boiling point under a given pressure can easily be found, because this would be the degree of heat which imparts to the vapour sufficient elasticity to overcome the pressure. So also a liquid may be made to boil at any given temperature; all that is necessary being to make the pressure less than the tension of the vapour. And it will readily be seen that these two terms are convertible; for, as the mean pressure of the atmosphere is capable of supporting a column of mercury 30 inches high, so the vapour which rapidly escapes from water in the act of boiling, having overcome the pressure of an elastic fluid like the atmosphere, must have itself at least the same amount of elasticity. Accordingly we find that the vapour of water boiling under the ordinary atmospheric pressure, will support a column of mercury of the same height as the atmosphere; and the tension or elasticity of aqueous vapour is measured by the height of the column of mercury which it will support. Thus,

			Inches of Mercury.
At 200°	the force of vapour of water	will support	23.64
205°	,,	,,	26.13
210°	,,	,,	28.84
212°	,,	,,	30.00
213°	,,	,,	30.60
214°	,,	,,	31.21
215°	,,	,,	31.83
220°	,,	,,	34.99
225°	,,	,,	38.20
230°	,,	,,	41.75

and so on, until we arrive at such a temperature that the elasticity of the steam can no longer be restrained by the sides of the boiler, which bursts with enormous violence. This subject will be further considered under EVAPORATION and STEAM.

The foregoing statements are usually illustrated by very beautiful and instructive class experiments. One of these is termed the *hydrostatic paradox*. A Florence flask F, Fig. 783, filled about one-third with water, is placed over a spirit-lamp E until the water boils: the steam issuing from the neck of the flask will expel the air, and while the steam is thus issuing, an accurately-fitting cork s must be inserted, and this may be made further air-tight by tying a piece of moist bladder over it and a portion of the neck. The flask may now be set aside for a few minutes, until it has cooled considerably: it is then to be immersed into cold water W, contained in a glass vessel R, when the water in the flask will begin to boil again with a violence proportionate to the coldness of the water. This beautiful experiment admits of easy explanation. When the flask is plunged into cold water, it is two-thirds filled with steam: the cold immediately condenses this into water, leaving a vacuum, and consequently no pressure above. The heat left in the water is sufficient to make it boil, and it continues to do so until a fresh atmosphere forming above it exerts a pressure sufficient to prevent any further ebullition at the temperature of the flask. If, however, the flask be plunged into ice-cold water, the steam will be again condensed, and the boiling will go on as before.

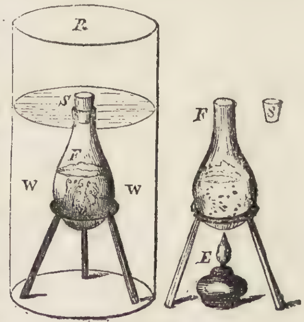


Fig. 783.

Thus it will be seen that boiling may go on at

almost any temperature, provided the pressure be removed. A glass of warm water under the receiver of an air-pump will boil when the air is pumped out; but the vapour that rises from it soon accumulates, and takes the place of the air in exerting a pressure, which puts an end to the boiling. To remedy this, M. Pouillet contrived an apparatus, in which the vapour is absorbed as fast as it is formed. It consists of a copper cylinder, shown in section C C′, Fig. 784, closed at its upper part with a screw-cap S. Before this is put in its place, a cylindrical cage of wire, full of fragments of quicklime, is placed in the copper cylinder. At the lower part is a tube *p*, which is connected with an exhausting syringe or with an air-pump, for making the vacuum. At the upper part are two bent tubes, to which are attached by screws the glass globes or other vessels containing the liquids which are to be boiled. By this arrangement cold water may be made to boil as easily as hot, and even at the freezing temperature it may be seen in violent ebullition. The difficulty of conveying a complete intelligence of experiments of this kind consists in the popular ideas connected with boiling. That a liquid should boil and not be hot seems to imply a contradiction; but we must consider that the definition of boiling is "the rapid formation of vapour at all points of a liquid," and that under ordinary circumstances this formation of vapour cannot take place, on account of the pressure of the atmosphere upon it, which is equal to about 15 lbs. on every square inch. Before the liquid can boil, this pressure must be removed, and the removal is usually effected by heat. If it were not for this pressure, it would be difficult, and in many cases impossible, to procure hot water. Boiling water might be at all times procured with the greatest facility; but it would not be hot, because the water, having little or no resistance to overcome, would burst into vapour at the first application of heat, just as it does in M. Pouillet's experiment on the removal of the pressure. Indeed, if it were not for the pressure of the atmosphere, the great waters of many parts of the earth would boil from the action of the solar rays, and its existence in the liquid state would in many cases be impossible.

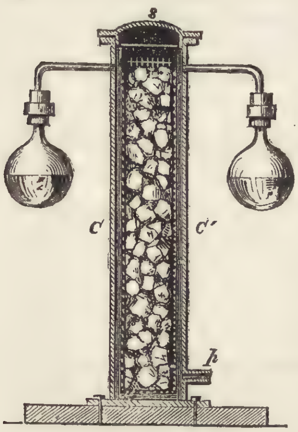
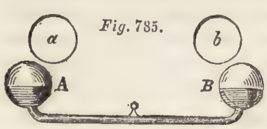


Fig. 784.

Dr. Franklin's pulse glass, Fig. 785, shows this curious property of liquids in a striking manner. A and B are two glass balls connected by a slender tube. One of them, A, is filled with water, and a small opening is left at the top of the other. On causing the water in A to boil, the vapour produced by it will expel all the air from the instrument, and when nothing but steam issues from the opening, it is closed up with a bit of wax, and the flame of a lamp being urged upon it with a blow-pipe, will close it hermetically. When the instrument is cold, grasp the ball A in the hollow of the hand; the heat of the hand will expand the bubble of vapour in it, and this vapour will drive the water into B, and blowing up through it will keep the water in B in a state of violent ebullition so long as there is any water in A. During this action B must be kept cold, in order to condense the vapour as fast as it rises up through the water. If we touch B with the warm hand or breathe upon it, the boiling ceases. When the water in A has all been driven into B, grasp B in the hand; the water will be driven into A, and the ebullition will go on in it as it did in B. While the boiling is going on in one bulb, the other will convey a sensation of cold to the hand in consequence of the rapid absorption of the heat by the particles of water converted into elastic vapour. This little toy may be suspended in the middle of the tube like a balance, and thus be placed in the inside of a window having two holes *a* and *b* cut in the pane in such a situation that when A is full of water and preponderates, B is opposite the hole *b*. When the room is sufficiently warm the vapour in A drives the water into B, which is kept cool by the air from without entering through the hole *b*. B then preponderates, and A being opposite the hole *a* the process is repeated in the opposite direction. Alcohol or ether tinged with carmine are sometimes used instead of water, and act with greater facility.

Fig. 785.



The boiling of liquids at low temperatures depending on low pressures, is of great importance in the useful arts. In the refining of sugar the syrup is in this way concentrated to the granulating point without risk of decomposition, as there was before the introduction of this plan. [See SUGAR.] A similar plan has been adopted in the preparation of certain medicinal substances, the properties of which are easily impaired by heat. [See EXTRACTS.] So, on the contrary, by exposing liquids to an increased pressure, we raise their boiling points in a proportionate degree. Thus in Papin's digester, [see DIGESTER,] the steam which is formed from the water having no means of escape, it exerts a pressure upon the water, and prevents the further formation of steam until the temperature of the water rises above the boiling point. This heat being conveyed to the steam, it now receives another portion of vapour without being condensed; and thus the quantity and elasticity of the steam are continually increasing with the temperature. Water has, in this way, been raised to the temperature of between 400° and 500°. Under such circumstances the solvent powers of water are greatly increased, some examples of which are given in the article BONE.

2. M. Pouillet has suggested that the cohesive attraction of the liquid may have some influence in modifying the principle, that at the boiling point the

elastic force of the vapour is equal to the superincumbent pressure. In fact, the small globules of vapour not being able to form without overcoming the cohesive attraction of the liquid particles which surround them on all sides, an additional elastic force due to a slight increase of heat is required beyond that which is necessary to overcome atmospheric pressure. When, however, the globules are once formed, the effect of cohesion is less effective, for being once overcome, the globules expand with a sort of spring, which contributes greatly to the disturbance of the liquid. If water be entirely free from air, so that the cohesion of its particles may act with the greatest effect, it can with certain precautions be heated to 275° without the cohesion of the particles giving way, or, in other words, without boiling. Some remarkable experiments on this subject are described in the article COHESION.

3. It is a remarkable fact that the boiling point of liquids is affected by the nature of the vessel containing them. Water boils a few degrees higher in a Florence flask than in an open vessel, and at a temperature 2° higher in glass than in metal, and it is only in open vessels of metal that the boiling point is regular. Liquids are converted into vapour more easily when they are placed in contact with angular and uneven surfaces than when the surfaces are smooth and polished. If a twisted piece of cold iron, metallic filings, or other finely-divided insoluble materials, be dropped into water in a glass flask which has just ceased boiling, the boiling will be resumed. Ether heated in a glass vessel had its boiling point lowered several degrees by the introduction of a few shavings of cedar; and alcohol, sp. gr. .849, had its boiling point reduced in the same way between 30° and 40°. If oil be present with water, the boiling point of the water is raised a few degrees in any kind of vessel. If a glass vessel be made perfectly clean by washing it with sulphuric acid or with potash, water may be raised in it without boiling to 220°. The adhesion between the water and the vessel is probably the cause of this irregularity; for where the vessels are thinly coated with sulphur, lac, or other material which has no adhesive attraction for water, the boiling point is sensibly lower than in clean metallic vessels. According to M. Marcet,[1] the temperature of the vapour from boiling water is the same as that of the water itself, only when the vessel, whether of glass or of metal, has a thin internal coating of some substance which has no sensible adhesion for water.

4. When the mass of liquid to be boiled has considerable depth, the inferior particles have to support, in addition to the pressure on the surface, the pressure due to the whole liquid column. If we suppose a boiler full of water to have a depth of 32 feet, the bottom layers would be under a pressure of two atmospheres, and consequently the globules of vapour could not form at a lower temperature than 250°, which is the boiling point of water at this depth and under this pressure. But the upper layers, which are under the pressure of only one atmosphere, boil at 212°; so that from the bottom upwards steam is formed at various temperatures between 250° and 212°. The bubbles of vapour formed at or near the bottom at this high temperature, ascend, and becoming suddenly condensed by the colder upper layers, produce those sudden jerks which are often inconvenient and even dangerous in boiling large masses of liquid. Where the depth of the liquid is small, a singing, simmering sound is produced, as in a kettle or a boiler of water over the fire. The bottom of the vessel in contact with the fire communicates its heat to the water in contact with it, and numerous minute bubbles of highly-elastic steam are formed; as these separate from the hot metal, they are burst in by the pressure of the fluid and the lower temperature, and the mass of water is thus thrown into a rapid and uniform vibration, producing a musical tone, which is graver or more acute according as the bubbles burst more or less rapidly in succession. The writer of the article STEAM in the Encyclopædia Britannica says:—"We have observed this phenomenon in greatest perfection when we have attached a slender pipe to a close boiler producing steam, and carried its open mouth, of the diameter of $\frac{1}{8}$th or $\frac{3}{16}$ths of an inch, down below the surface of cold water in a glass jar. When the mouth of the steam pipe is held just below the surface of the water, the steam issues in great rapidity in small bubbles producing an acute tone; and, on the other hand, when the pipe is held at a considerable depth, the concussions become more violent and louder, their intervals of succession greater, the tone is lowered, and finally the shocks become detached, and so violent as to shake the glass and surrounding objects with much force." Professor Robison has also remarked, that if we suddenly plunge a lump of red-hot iron into a vessel of cold water, taking care that no red part be near the surface, and apply the hand to the side of the vessel, a most violent tremor is felt, and sometimes strong thumps, arising from the collapsing of very large bubbles. If the upper part of the iron be too hot, it warms the surrounding water so much that the bubbles from below come up through it uncondensed, and produce ebullition without concussion. The great resemblance of this tremor to the sensation experienced during the shock of an earthquake, has led some to suppose that the shock is produced by the sudden contact of incandescent matter with water.

5. The boiling point of a liquid is not changed by substances mechanically suspended in it, such as sand; but it is always changed by the presence of bodies which combine chemically with it. All the soluble salts, for example, raise the boiling point of water; nevertheless the vapour from these solutions consists of water perfectly pure, without any trace of the substances dissolved.[2] The following are the

(1) "Annales de Chimie et de Physique." 3 Série, tome v. 1842. This memoir contains much curious and important information, calculated to disturb our faith in the accuracy of the boiling point as marked upon our chemical thermometers.

(2) There appear to be some exceptions to this statement, as, for example, in the manufacture of salt from brine, as carried on in some parts of Germany. An experiment was tried at the salt works of Nauheim, in which a plate of glass was placed upon a

boiling points of a number of saturated solutions of salts:—

Name of salt.	Dry salt in 100 parts of solution.	Boiling point.
Acetate of soda	60	256°
Nitrate of soda	60	246°
Nitrate of potash	74	238°
Sal ammoniac	50	236°
Common salt	30	224°
Sulphate of magnesia	57	222°
Alum	52	220°
Chlorate of potash	40	218°
Sulphate of copper	45	216°
Sulphate of iron	54	216°
Acetate of lead	42	215°
Sulphate of soda	31	213°

Connected with the subject of ebullition, and interesting also in an industrial point of view, are the phenomena presented by liquids on the surface of highly heated metals. The Editor, writing on this subject so far back as the year 1836,[1] has the following remarks:—"When water falls upon a red-hot iron plane surface, it suddenly divides into drops—each drop assumes a spherical form, and remains upon the plate longer than would seem natural, considering the high temperature to which it is exposed. Now, if a platinum crucible be brought near to a white heat, and water be allowed to fall into it drop by drop, the crucible may be nearly half filled with water, and be kept in this state for some minutes without any perceptible evaporation. A piece of cold glass or metal will receive no deposit of moisture, if held for a moment within the crucible, and the water suffers diminution almost imperceptibly. In this state the water will be observed to be in rapid motion, 'rotating about an axis perpendicular or nearly so to the lowest point of the dish, and at the same time its figure changes, and, from being circular in its horizontal section, becomes of an irregular oval, which contracts and dilates alternately as the mass revolves; the transverse axis contracting until its place is occupied by the conjugate, and *vice versâ*. The direction of this rotation is not at all uniform, and the mass sometimes becomes quiescent, and then assumes motion in an opposite direction. When this state of things first begins, vapour sometimes bubbles or bursts up through the liquid; but when fully established, it is most copiously given off below. In fact, the appearance is that of a stratum of vapour between the water and the bowl, which becomes at times visible when condensed at the edges.' [2] This description, which applies to water in a heated copper bowl, expresses with tolerable accuracy the phenomena presented by water in a heated platinum crucible. Much, however, depends on the quantity of water employed, and the kind of surface upon which it falls. If the platinum crucible be large, and the bottom slightly convex within, the water on reaching the bottom divides into globules, each of which is a perfect sphere, and rotates with great rapidity on its vertical axis, and at the same time it has a dancing onward sort of motion. If the bottom of the crucible be quite flat, and be kept exactly horizontal, similar effects ensue; but the experiment succeeds best when the interior of the crucible is a portion of a hollow sphere, and the inner surface perfectly clean and bright. The water must fall in slow drops, or the surface of the metal will be wetted, and steam generated; but if the drops follow each other with moderate slowness, an atmosphere of steam is immediately formed, which surrounds the globule, prevents its contact with the heated metal, and so protects it from vaporization. These facts are remarkable enough, and it is no less remarkable that if the source of heat be removed, and the crucible allowed to cool for a few minutes, a portion of the water will suddenly burst into vapour and be dissipated."

In the paper already referred to, the Editor was the first to show that other fluids behaved in the red hot crucible in a manner similar to that of water. The liquids tried were pyroligneous ether, sulphuric ether, alcohol, and mercury. Oil of turpentine, olive oil, and sulphuric acid were decomposed. In the "Student's Manual of Natural Philosophy," published in 1838, the Editor made the following observations:—"If a polished metallic vessel, such as a platinum crucible, be brought to a red or white heat, and several drops of water be allowed to fall into it, they unite into a globule, which spins rapidly round without ebullition. . . It is necessary to the success of this experiment, that the globule be not in contact with the heated metal; and accordingly we find that if the vessel be removed from the source of heat, and allowed to cool down to a certain point, a portion of the water flashes into steam by coming into contact with the heated metal. The author of this work has found that these phenomena apply also to ether, alcohol, mercury, and many saline solutions, but not to oils. He has also varied the experiment by employing a fixed oil at the temperature of 450° or 500°, instead of the heated metal. When turpentine is dropped upon it, it forms a disk with a perfectly well defined edge: the disk rotates rapidly in a horizontal plane, and soon disappears by evaporation. If several drops of sulphuric ether be placed upon the heated oil, they unite and form one large globule, which appears to be a perfect sphere: this rotates with great rapidity upon its axis, and moves rapidly over the surface of the oil. If now we place a drop of water upon the heated oil, it will form a similar figure to the ether, and behave in the same manner for an instant or two; but when the two globules come near each other, they unite and form one drop, which continues to rotate until it disappears by evaporation; or as it sometimes happens, the drop formed by the union of ether and water sinks below the surface of the oil, bursts into vapour, and scatters the oil about with considerable force. Hence much caution is required in conducting this experiment. In some cases, however, when the globule sinks below

tall pole between two evaporating houses, distant about 1,200 paces from each other: it was found in the morning, after the drying of the dew, that the glass was covered with crystals of salt on one or the other side, according to the direction of the wind. Pallas also remarked that in the neighbourhood of the salt lakes of Asiatic Russia the dew was salt to the taste.

(1) See Mechanics' Magazine, No. 703.

(2) American Report on the Bursting of Steam Boilers.

the surface of the oil, an equable atmosphere of vapour is formed around it; so that becoming specifically lighter than the oil, it is instantly thrown up again to the surface without bursting into vapour, and it continues to rotate on the surface of the oil as before. . . Alcohol, pyroligneous ether, naphtha, and bisulphuret of carbon form globules on the surface of hot oil; which globules behave in the same manner as sulphuric ether. Ether also forms a rotating globule on the surface of hot water and hot mercury. If sulphuric acid be heated to about 400°, and a drop of ether be placed on the surface, it forms globules which dart about with astonishing rapidity: alcohol also forms globules: but naphtha and turpentine form disks which soon disappear with decomposition, and their carbon blackens the acid." In all these experiments, the drops of water were placed upon the hot surfaces by means of a pipette, which allowed them to be placed on very gently. It is curious that water, whose specific gravity is so much greater than that of hot oil, should rest upon it and move about with rapidity; but in all these cases the globules of water, ether, &c., are surrounded by steam, which serves as a sort of cushion for them to rest upon, and preserves them from contact with the heated surface whether of metal, oil, or sulphuric acid.

In the year 1845, the Editor had the pleasure of witnessing in the laboratory of King's College, London, some beautiful experiments by M. Boutigny of Evreux. This gentleman freely admitted the Editor's priority in the results above stated, and he also showed a number of beautiful experiments which tend to throw additional light on this curious condition of water, which he terms the "spheroidal state." In the first place, M. Boutigny proved that a red or white heat is not necessary in order to throw water into this globular or spheroidal form, for on dropping some water into a saucer of lead, a metal which melts long before it becomes luminous in the dark, the water rolls about like a little crystal ball for a considerable time. A spheroid of water was formed in a metallic capsule floating on oil heated to not more than 340°, which is about 600° below what is usually termed "red heat." Liquids more volatile than water become spheroidal at still lower temperatures: Alcohol at 273°; ether at 140°; and it was found in general that those liquids which require the highest temperature for boiling, require also the highest to make them assume the spheroidal state.

Water and other liquids in the spheroidal state disappear by slow evaporation. A quantity of water which, under ordinary circumstances, would boil away in one minute at the temperature of 212°, will, if thrown into a vessel heated nearly to redness, require little less than an hour for its total dispersion.

The temperature of water in the spheroidal state was ascertained in the following manner. Let a large spheroid of water be formed in a tolerably thick crucible of platinum or silver, and the bulb of a small and delicate thermometer be carefully plunged into the middle of it, taking care not to allow it to come in contact with the heated metal. The temperature of the water will be found to be 205°. No variation in the temperature of the vessel containing a spheroid affects the temperature of the spheroid itself. A spheroid of water in a crucible heated considerably below redness is just as hot as one contained in a crucible heated to whiteness in a blast furnace. However high the temperature of the containing vessel may be, bodies in the spheroidal state remain constant at a temperature below that of boiling. Thus alcohol, which usually boils at 173°, never rises in the spheroidal state higher than about 170°; and ether, which boils at about 100°, when thrown into a crucible heated to whiteness does not rise above 95°. It is also remarkable that if the liquids be dropped in a boiling state into the red-hot vessels, they cool down below the boiling point in assuming the spheroidal state, and when once in this state the globules do not absorb or transmit, but reflect the rays of heat which impinge upon them.

The effect of dropping a liquid whose boiling point is very low into the red-hot crucible is truly remarkable. Sulphurous acid at the temperature of 45° cannot be kept in a liquid state, except under the pressure of two atmospheres, or about 30lbs to the square inch of surface. At a less pressure than this it bursts into vapour, and even when cooled down to 14° it boils just as water does when heated to 212°. The boiling point of sulphurous acid is therefore 14°. Now, when a few drops of this acid are allowed to fall into a red- or white-hot crucible, the temperature actually falls to 12°, in obedience to the law observed in other cases; and if water be at the same time poured into the white-hot crucible, it becomes frozen into a solid lump of ice. Dr. Faraday has even succeeded in freezing mercury in a red-hot platinum crucible: he first introduced ether into it, then solid carbonic acid, and into this mixture, in the spheroidal state, he plunged a metallic capsule containing mercury. In two or three seconds the mercury froze into a solid lump.

It has been already shown that a globule of water or other liquid is not in contact with the hot surface. This may be proved in several ways. Thus, "if a spheroid of some opaque substance be formed on a nearly flat surface, and then interposed between a lighted candle and the eye, the image of the flame is distinctly seen between the hot surface and the globule. This effect might be produced if the spheroid were in a state of rapid motion up and down, since the image of the candle, seen during the ascent, would remain visible till the next ascent; just as an ignited point in rapid revolution appears as a circle of light. That this is not the case, however, may be shown in another way. If silver be touched with nitric acid it is rapidly corroded, and in a short time dissolved. But if a quantity of nitric acid be poured into a crucible or dish of silver, sufficiently hot to induce the spheroidal state, no corrosion whatever will take place; clearly proving that the acid is at no time in absolute contact with the metal. That this is not owing to any deficiency in the strength of the

acid, may be seen by placing in the spheroid a piece of cold silver, when violent action of course takes place, nitrous fumes being given off, and nitrate of silver formed."[1]

If a large spheroid of water be formed on a nearly flat surface, and a small bar of white or red-hot iron be thrust into the middle of it, contact being impossible between the bar and the water, the latter forms a ring at some little distance from the heated bar, presenting very much the appearance of Saturn and his ring. So also if a lump of silver at a glowing red heat be plunged into a glass of water, as long as its bright redness is maintained, there is no ebullition, but as it slowly cools, boiling takes place. In this experiment, the glowing metal appears to form round itself an atmosphere, preventing the contact of the water, the contiguous surfaces of which appear like a silvered plate. Such phenomena as these must have some influence on the hardening and tempering of metals. If the metal to be hardened is in a highly incandescent state, the effect will not be produced on plunging it into water. A certain temperature should therefore be observed in such cases.

M. Boutigny thought that the bursting of steam boilers may be referred to the spheroidal condition of water. In illustration of this view, he exhibited the following experiment. A sphere of copper was heated, and water dropped into it: it was securely corked, and the lamp was then withdrawn. As long as the metal remained red, everything was quiet, but upon cooling, the water gradually ceased to be supported on its cushion of steam, and being brought into actual contact with the hot metal, flashed into steam, and the cork was blown out with explosive violence. We learn from Mr. Bowman's lecture that a spheroid composed of between four and five pints of water has been in this way experimented with, when the sudden formation of highly elastic steam was very striking. In this way, says M. Boutigny, is resolved the singular problem, "Required, to fill a vessel with water without wetting it, and to make the water boil by cooling the vessel."

Now, to apply a case of this kind to a steam boiler. Suppose that the engine-man neglect to supply it with water, or that the feed-pipe is out of order; the furnace all the time being in action, it is possible for all the water to be evaporated, and for the boiler to become red-hot. If, under these circumstances, water be thrown in, the first portion becomes spheroidal, and continues so until, by the addition of a larger quantity, the boiler is so far cooled that the spheroidal form can no longer be maintained: the spheroid comes in contact with the overheated boiler, bursts into steam, or, in other words, suddenly increases in bulk 1,700 times (1 cubic foot of water forming 1,700 cubic feet of steam), and the consequence is that the boiler bursts.

In Mr. Armstrong's "Treatise on Steam Boilers," published in Weale's Rudimentary Series, another very probable cause of water becoming spheroidal is mentioned. After alluding to boiler incrustations, and their action in preventing the passage of heat from the furnace to the water, owing to their non-conducting property, he says:—"It is known that an internal coating of incrustation, or boiler scale, is liable to crack, and separate into large pieces, which are thrown off from the boiler bottom at some particular degree of temperature, depending upon the thickness of the scale and the kind of substance of which it is formed. We can easily suppose that by a little hard firing, and unduly heating the boiler, a large portion of scale may be suddenly detached, uncovering a considerable area at a temperature something exceeding the maximum evaporating point, which is well known to be considerably under the lowest red-heat of iron. Now, the first effect produced will evidently be a certain amount of repulsion between the overheated iron and the water, which may continue for several seconds, and perhaps a few minutes: this may account for the sudden decrease in the supply of steam that has sometimes been observed just before the explosion of a boiler has taken place. There must also be a gradual diminution of temperature during this short space of time, in that part of the overheated iron which is exposed to the water (creating a contraction of the metal), increasing as the decreasing temperature of the iron approaches the maximum evaporating point, which is at about 350° to 400° Fahr., and causing a corresponding strain on the rivets in the boiler bottom. The direction of this strain may generally be traced on examining the bottom plates of any old boiler, and will be found to radiate in lines proceeding from the part which has been most acted on by the fire. . . . When an incrusted boiler bottom becomes highly heated, and the water at the same time too low, it very commonly happens that a large quantity of water is immediately let in, when the consequences are similar to those just described; for the internal coating of scale being suddenly contracted by the cooling effect of the water admitted, it is detached in the same manner as it would have been by the expansion of the iron, and the same effects produced, although, perhaps, more speedily, as the water admitted will reduce the temperature of the exposed part of the boiler bottom more rapidly to the maximum evaporating point.

"Whenever a boiler bottom is seen, or supposed to be, approaching to redness, (and that can only happen when the water is not boiling, or when the engine is standing,) the engine-man should be cautioned against allowing a fresh supply of water to go into the boiler, whether the boiler is short of water or not, until after the engine has been some time at work. My advice to engine-men in such cases is not to start the engine at all, but to open the fire-doors, and stand at a safe distance until all goes cool. I would not have him stop to pull the fires out, and on no account to open the safety-valve, as being little less hazardous than starting the engine. If, indeed, he knows the safety-valve to be overloaded or made fast, and the

(1) "On some remarkable properties of water," &c.; a lecture read before the Royal Manchester Institution, 17th February, 1845, by J. E. Bowman, Demonstrator of Chemistry in King's College, London.

steam still continues to rise with the fire-doors open, the fires may then be quenched by a jet of water from a hose pipe, or other safe means."

It has been found that smooth and even surfaces of metal when heated are more favourable to the spheroidal state of water or other liquids, than rough surfaces, or surfaces covered with projecting points. There is an objection to fixing projecting points in a steam-engine boiler, on account of the difficulty they would occasion in cleaning it out; but M. Boutigny suggested there should be thrown into the boiler loose pointed pieces of iron of such a shape that one of the points should always be uppermost.

The spheroidal condition of liquids helps to explain the remarkable experiment of handling molten metals, which has sometimes been mentioned in scientific books, but which no scientific man had the hardihood to repeat until M. Boutigny showed that it could be done with impunity. To mention one out of numerous instances recorded of this feat, Beckmann states that in September, 1765, being at the copper-works at Awestad, one of the workmen took some of the melted copper in his hand, and after showing it to the company, threw it against a wall. He then squeezed the fingers of his horny hand close to each other, held it a few minutes under his arm-pit to make it perspire, as he said, and taking it out again, drew it over a ladle filled with melted copper, some of which he skimmed off, and moved his hand backwards and forwards very quickly by way of ostentation.[1] M. Boutigny and M. Michel have performed similar experiments with cast-iron. The latter gentleman says:—"I divided, or cut across with my hand, a jet of cast-iron issuing from a cupola furnace, and I also plunged my other hand into a ladle of cast-iron in the molten state which was fearful to look at. I trembled involuntarily in making the trial, but both hands escaped uninjured." The explanation of this experiment is that the moisture of the hand is thrown into the spheroidal state, which preserves it from contact with the molten metal, and by reflecting the radiant heat, is kept at a point below boiling. M. Boutigny's experiments were recorded in a pamphlet which is now out of print, but they are stated fully in Bouchardat's "Physique Elémentaire," Paris: 1851.

EFFERVESCENCE, a term applied to the escape of a gas from a liquid with a sort of hissing sound, resembling the simmering or boiling of water, as in soda-water powders, in which the carbonic acid of sesquicarbonate of soda is set free by the action of tartaric acid. When a chemical solvent is applied to a solid, effervescence is sometimes produced. The solution of a solid containing carbonic acid in an acid is generally conducted in a flask, and requires certain precautions. "During a cold effervescence, as of carbonate of lime in an acid, the breaking of the bubbles will throw up a shower of particles, many of which will ascend several inches perpendicularly. In these cases it will be right to incline the flask at an angle of about 45°, for then the rising drops will meet with and break against the side of the flask, and be retained. At other times, when strong currents of vapour or gas are produced at the same time with this dispersion from the breaking of bubbles, many of the particles may be carried away by the current, even when the flask or vessel may be considerably inclined. In these cases, the addition of the acid, or the application of heat, should be made cautiously, that the current may not become so rapid and attain such power as to do harm. For the same reason, operations which are liable to occasion much effervescence, should be performed in flasks of the largest size, that the current of gas within may have less velocity, and that the particles may have room and time to fall."—*Faraday.*

(1) Beckmann, "History of Inventions," vol. ii. chapter on Jugglers, &c."

EFFLORESCENCE. See Deliquescence.

EIDER-DOWN. The produce of the Eider-duck, (*Somateria mollissima,*) one of the largest of the duck tribe, celebrated for the value of the down on its breast, which is extremely light and soft, and makes the warmest covering known. The native country of this bird is from about 45° north to the highest arctic latitudes yet explored. The southern European boundary of their breeding places appears to be the Faroe Islands, off the coast of Northumberland, and the rocky islands beyond Portland, in the district of Maine; but they are not very numerous in either of these localities. They always prefer to make their nests in small islands, seldom being found on the shores of a large island, or ever on the mainland. On this account, the Icelanders, who are well aware of the value of this bird, take a great deal of pains to form islands by cutting off from the mainland certain of the smaller promontories, and irregularities of their coast. On these secure spots, free from the intrusion of land animals, the birds select a sheltered place for the nest, which is made of tufts of sea-grass, or bundles of sea-weed cast up by the tide, and is thickly and carefully lined with the down which the female plucks from her breast. She is so unsparing in this material, that she heaps it up into a thick puffed roll all round the nest, and when forced to leave her eggs in order to search for food, she prudently turns this marginal roll of down over the eggs, to keep them warm. But she cannot ensure them against the rapacity of the down-collectors. As soon as it is observed that the first eggs are laid, they are removed, and at the same time the nest is robbed of its down: the patient bird again provides a supply, but not so abundant as the first. But ere long this second supply, and the eggs embedded in it, are likewise stolen: she then makes one more attempt, sometimes, it is said, gaining a portion of down from the breast of her mate for this third nest; but when that also shares the fate of the other two, she deserts the spot in despair.

When allowed to hatch her eggs, usually four in number, she early takes the young ducks to the water, and swimming with them on her back to some distance, she makes a sudden dive, and so leaves them to swim for themselves. If the nest is disturbed, and if the first four eggs are removed, the bird goes on laying

for several weeks. Thus there is a double inducement to rob the nests, for the eggs furnish excellent food, and the down is greatly in request in a commercial point of view. It is sold, when cleaned, at from twelve to fourteen shillings per pound, and in one year it has produced to the Icelanders nearly 1,000*l.* sterling. The down has such extraordinary elasticity that three-quarters of an ounce were sufficient to fill a large hat. It is a remarkable fact, however, that this extreme elasticity only belongs to the down plucked by the bird herself for the comfort of her young, and scarcely exists, or only in a very inferior degree, in the down taken from dead birds. No doubt the plumage is in its best condition at the time when it is wanted as a mantle for the young birds. The quantity produced is various. The contents of a first nest were once described as yielding half a pound of down; but this appears to be an extreme quantity when compared with other accounts, which make mention of less than an ounce. The latter, however, were the results obtained at the southern breeding places, and it is to be expected that the northern are more liberally supplied. The hardy inhabitants of Norway, Iceland, &c., make no use of it; but they send abundant supplies for the luxurious beds and coverlets of the wealthier classes of the south.

EIDOGRAPH. See PANTOGRAPH.

ELAINE. See CANDLE.

ELASTICITY. The particles of solid bodies appear to be held in equilibrium by two forces, one attractive and the other repulsive, so that any mechanical force which tends to disturb them from this state is more or less resisted; and a substance is said to be more or less *elastic* according to the facility with which it regains its form, bulk, or volume when the disturbing force ceases to act.

While this property is being displayed, the change of form is evident in many bodies; as, for example, in a strip of steel fixed at one extremity: on drawing it aside by the other extremity, and leaving it to itself, it recovers its form by a series of oscillations on either side of its position of rest. It is evident that in this case the molecules have been disturbed from their position of equilibrium, and that it is the force with which they tend to return thereto that constitutes the elasticity of the body in question.

But there are many cases in which elasticity is displayed without the change of form becoming evident. For example, if we allow an ivory billiard-ball (or a ball of wood, stone, glass, or metal,) to fall upon a smooth slab of marble or of metal, it will bound up again nearly to the height from which it fell, and it would attain that height completely were it not for the resistance of the air. Now the change of form in the billiard-ball is not in this case evident, but it may be made so by covering the slab with a thin layer of oil. If we then let the ball fall upon it, and examine the spot which the ball had struck, a mark will be seen in the oil, not of a mere point, as would have been the case had the surface of the ball not yielded at the instant of impact, but a mark over a considerable surface, showing how much the ball became flattened; and this mark will be greater in proportion to the height from which the ball is allowed to fall.

The property of elasticity may be said to exist in various degrees in all substances. It is most perfect and extensive in aëriform bodies, as already explained in the article AIR, p. 27. It is perfect, but not extensive, in water and liquids generally. The means by which the elasticity of liquids was ascertained, belong to the triumphs of modern science. It was long supposed that water was incompressible, and consequently non-elastic; an assumption which derived support from an experiment made in 1661 by the Academicians of Florence. They filled a hollow ball of gold completely full of water, and submitted it to great pressure, whereby the water was made to weep through the pores of the gold, or to appear as a fine dew on the surface. The compressibility of water was proved by Œrsted, a Danish philosopher, and the apparatus used by him is shown in Fig. 786. A B C D is a strong glass cylindrical vessel with a smaller metal cylinder, A E F B, fixed firmly at the top of it; this smaller cylinder contains an air-tight piston, K, movable by means of a screw. M is a glass bottle, in the neck of which is fixed by grinding, one extremity of a capillary tube, *a a*, open at both ends. The bore of this tube is very fine, and it is important to ascertain accurately the precise fraction of the contents of the whole bottle which each inch in length of its bore will hold. This is done by weighing the quantity of mercury which the bottle will hold, and the quantity which an inch of the bore of the tube will hold. In some of the tubes used by Œrsted, each inch in length was found to hold 80 millionths of the contents of the bottle.

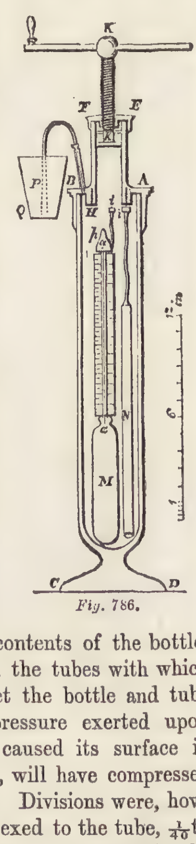


Fig. 786.

Supposing these to have been the tubes with which his experiments were made, let the bottle and tube be filled with water. Any pressure exerted upon this water which will have caused its surface in the tube to descend one inch, will have compressed it by 80 millionths of its bulk. Divisions were, however, marked upon a scale annexed to the tube, $\frac{1}{40}$th of an inch apart. A depression of the water in the tube through any one of these divisions, would thus indicate a compression of two millionths. This compression was produced in the following manner:—The bottle and its apparatus are introduced into the glass vessel A B C D, the part A E F B having been unscrewed to admit them. This vessel is then to be filled with water, and the cylinder A E F B is replaced, its piston K having been first screwed down as low as H. This piece being firmly fixed to the piston, is

ELECTRO-MOTIVE MACHINES AND MAGNETO-ELECTRIC MACHINES. It is proposed in the present article to bring together, *first*, a few details respecting voltaic electricity as a source of motive power, and, *secondly*, to state the conditions under which the magnet may be made to supersede the voltaic battery in the art of Electro-plating and gilding, &c. Although these two subjects are not very intimately connected, yet they have a common tie, and will be of more interest immediately after the articles on the ELECTRIC TELEGRAPH and ELECTRO-METALLURGY than if deferred.

The property of a voltaic current to convert soft iron into a magnet, and the disappearance of the excited magnetism the moment its action is suspended, have already been noticed. [See ELECTRIC TELEGRAPH.] This property has placed at command a very considerable force, which has been applied by ingenious men as a moving power. Up to the present time no great success has attended the production of electro-magnetic machines, and it will always be a serious question, whether the zinc fuel which is burnt to produce electricity is not more costly than the coal fuel which is used to produce steam in the steam-engine. It certainly does appear to be a circuitous process, first to burn our coal in order to smelt our zinc ore, and then to use the zinc as a fuel for producing power.

The general principles observed in the construction of electro-magnetic engines are, to produce a rapid change of polarity in masses of iron, surrounded by spiral coils of insulated wire, so as to cause them alternately to attract and repel other electro-magnets brought within their influence; or masses of iron are rapidly magnetized and demagnetized without change of polarity, by which means an attractive force is exerted upon other masses of iron so long as the attraction pulls them onward in one direction, and no longer. In either case a rotatory motion is obtained by fixing the masses of iron on the circumference of a wheel, and placing the wheel so as to allow the electro-magnets to act upon the extremities of its radii, as is usual in the application of a moving force to the circumference of a wheel.

By means of an engine on this principle, Professor Jacobi, of St. Petersburgh, in 1838 and 1839, succeeded in propelling a boat upon the Neva at the rate of four miles an hour. This boat was 28 feet long, about 7 feet wide, and drew nearly 3 feet of water. It contained ten persons. The engine was worked by a voltaic battery of 64 pairs of plates, and it propelled the vessel through the medium of paddle-wheels. In 1848 Mr. Llewelyn exhibited to the members of the British Association a similar experiment on a lake at his residence near Swansea. A small boat was propelled with considerable force by means of a screw, worked by an electro-magnetic engine. Jacobi applied his engine to the working of machinery, but not with any great success. In 1842 Mr. Davidson constructed an electro-magnetic locomotive engine, which was tried on the Edinburgh and Glasgow Railway; the carriage was 16 feet long and 6 feet wide, and, including the batteries and magnets, weighed above five tons. It was propelled at the rate of about four miles an hour.

Various forms of electro-magnetic machines have been invented by Wheatstone, Talbot, Hearder, Hjorth, and others, but it is not likely that such machines will meet with much encouragement while coal, the food of the steam-engine, is abundant. That a great force may be commanded is evident from the fact, that an electro-magnet lately exhibited in London attracted a mass of iron at $\frac{1}{8}$th inch distance with a force of 1,344 lbs., and it required

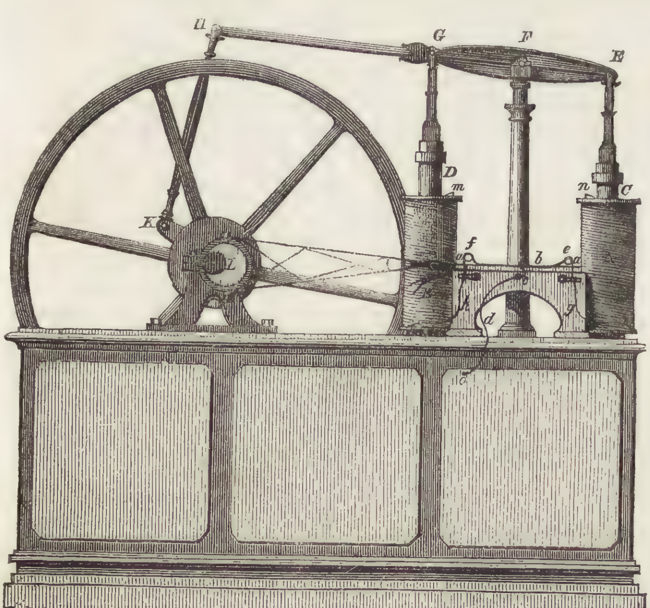


Fig. 838 ELEVATION OF ELECTRO-MAGNETIC MACHINE.

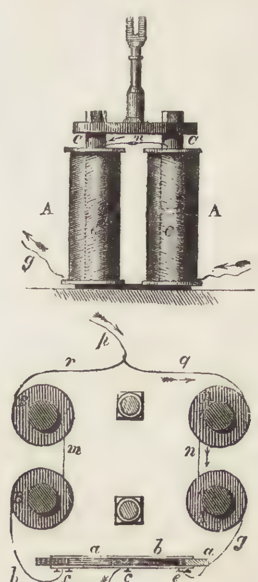


Fig. 839.

no less than 4,764lbs., or more than two tons, to separate the contact.

It may be interesting to give the practical details of one of these electro-motive machines. Without in the slightest degree intending to undervalue the merits of other machines, we select one, the invention of M. Froment, that has excited a good deal of attention in Paris. In this machine four hollow cylinders, two of which are seen at A, B, Fig. 838, are surrounded by a great length of wire, covered with silk, for the purpose of conveying the electric current. Solid cylinders of soft iron C D enter without friction into the hollow cylinders. The cylinders C, Fig. 838, and C C, Fig. 839, are united at their upper part by a transverse piece, also of soft iron: these cylinders are suspended at the extremity E of the beam E F G and the cylinders D are also suspended from the point G. Motion is communicated to the pieces C D, by the action of the electricity, by which means the beam is made to oscillate on the point F in the manner about to be explained. This beam is produced as far as H, where it is hinged to a connecting rod H K, the lower extremity of which is attached to a crank K L. The oscillation of the beam thus produces the rotation of the crank, which is regulated by the fly-wheel.

In order to understand how it is that the electricity gives motion to the pieces C D we must refer to the upper part of Fig. 839, in which are represented the iron cylinders C C inserted within the hollow cylinders A A, about half-way down. Two other iron cylinders C′ C′ occupy the lower half of the hollow cylinders, and are connected together by an iron pin passing below them. Thus we have two distinct horse-shoe arrangements, C C and C′ C′, both placed in such a manner as to become powerfully magnetized when the voltaic current is allowed to circulate round the cylinders A. The two magnets formed in this way have the poles of opposite names opposed to each other, so that they attract each other, and tend to unite; but as the magnet C′ C′ is fixed, the magnet C C is set in motion, thereby pulling down the extremity E of the beam. No sooner is this done than the voltaic current ceases to circulate round the cylinders A, and consequently the bars C C, C′ C′, becoming demagnetized, cease to attract. At the same moment the current is made to pass round the cylinders B; the bars D, becoming magnetic, are attracted down thereby, also lowering the extremity G of the beam. Having produced this effect, the electricity ceases to circulate round B, but passes over to A, and so on alternately.

In order thus to make and break contact in succession, the axis which is made to revolve carries an eccentric L, which gives a reciprocating motion to a slide *a a*. This slide is formed of a small plate of ivory, and is covered in a portion of its length with a metallic strip *b*. A copper wire *c* is bent so as to press constantly with its point upon this metallic strip, notwithstanding the reciprocating motion which it receives from the eccentric L. This wire communicates with one of the poles of the voltaic battery by means of the conducting wire *d*, which enters at *o* into the chest containing the battery. Two other copper wires *e f* also rest with their points on the slide *a a*, and communicate one with the wire *g*, which comes from the cylinders A, the other with the wire *h*, which proceeds from the cylinders B. The reciprocating motion of the slide *a a* brings the plate *b* alternately under the wires *e* and *f*, so that the wire *c* is put in communication at one moment with the wire *g*, and at another with the wire *h*, by means of the metallic plate *b*. All this will be better understood by referring to the lower part of Fig. 839, which is a horizontal section of this portion of the machine. Here we see that the electric current proceeding from one of the poles of the battery along the wire *p* completes its circuit by passing over to the wire *d*, and in doing so it can follow one of two different roads, according to the position of the slide *a a*. In the position shown in the figure the current passes from *p* to *q*; then turns round and ascends the first cylinder A; passes by the wire *n* to the second cylinder A, round which it circulates in descending, and it quits this second cylinder by the wire *g*, and proceeds from *e* to *c* by means of the metallic plate *b*; lastly, the current returns to the battery by the wire *d*. It will be seen in this case that the course of the current round the cylinder B is interrupted, because the portions *f c* of this path now consist of the non-conducting ivory. When, however, by the rotation of the axis the eccentric brings the metallic plate *b* in contact with the wire *f*, the electricity circulates round the cylinders B, and does not pass round the cylinders A.

The most powerful engine of this kind yet made has been equal to one horse. The inventor uses these electro-motive machines to give motion to dividing engines for graduating the limbs of circles for measuring angles. The results are said to be very satisfactory.[1]

In proceeding to notice those forms of apparatus which have been contrived for supplying current electricity without the intervention of a voltaic battery, we must enter into some scientific details which are important to be clearly understood. The voltaic battery is at all times a constant source of trouble and expense, and it would certainly be a great advantage if it could be superseded by a magneto-electric machine.

The intense degree of *magnetism* induced by dynamical electricity (*i. e.* by the *motion* of *electricity*) led naturally to the expectation of a converse action, viz. a disturbance of *electricity* by the *motion* of *magnets*; but for many years all attempts to exhibit this action failed, and many intermediate steps were necessary to pave the way for Faraday's great and long-sought discovery of *magneto-electricity*.

The first of these steps was the discovery of *secondary currents*, or the induction of one voltaic current by another. If wires forming parts of two distinct circuits, and completely insulated from each other, be made to run parallel and very near together for a considerable length, although the steady flow of a current through one wire produces no effect on the other

(1) Delaunay, Cours Elémentaire de Méchanique. Paris, 1851.

wire, yet if this current be suddenly stopped, a momentary current or *wave* of electricity flows through the second wire in the same direction as the current which has just ceased; and if the original current be suddenly re-established, another such momentary wave is induced, but in the contrary direction. These secondary currents are also induced in the same wire with the inducing current, from which they are distinguishable by several characteristics, but chiefly by their greater intensity or power of forcing a way through imperfect conductors. Hence they give sparks and very intense shocks in cases when the primary current could not penetrate the thinnest layer of air, or affect the most sensitive nerves. Hence also arises the singular effect of passing a feeble current through a *coil, i. e.* a great length of wire, covered with silk or other insulating matter, and then wound on a reel. This imitates, with a single voltaic pair, some of the effects of a multiple battery; not, indeed, producing any augmentation of the continuous effects, such as electrolysis and the heating of wires, but only of those effects which are confined to the moment of breaking the circuit, such as the spark and shock; for at that moment all the turns of the coil react on each other, all tending to induce a current in one direction, which current therefore resembles that set in motion by a very numerous series of very small and weak batteries—it has no greater quantity than if it were induced by a single turn of the coil, but a far greater momentum, or power of overcoming resistances.[1]

The next step was the discovery, that these effects were greatly exalted by the presence of an iron core or electro-magnet within the coil.

Faraday also found that secondary currents might be induced not only by the sudden commencement or stoppage of the primary current, but by the sudden approach to or removal from each other of two wires, in one of which a continuous current is flowing. The approach of the inducing wire induces a current in the contrary direction; its removal, a current in the same direction as its own.

Now putting together all these facts, and bearing in mind that a magnet acts in all respects like a cylinder or bar, in which currents are constantly circulating round the axis in one direction, it will be seen that there are two modes of proceeding, by which we may expect to make it induce momentary currents in a surrounding cylinder or helix; 1. by suddenly demagnetizing or remagnetizing it, or still more forcibly by changing its poles; 2. by suddenly withdrawing it from the helix, or reinserting it. This latter is the easier experiment, and afforded the first instance of an electric current excited by the magnet alone, but then the current was too weak to be recognised by any other than its magnetic effects on a galvanometer, so that, to avoid all appearance of reasoning in a circle, it became very desirable to exhibit this new property of the magnet, not merely as magnetism, but as electricity.

In trying the other experiment (1) the destruction or reversal of polarity was at first accomplished by electricity, thus:—

On a ring of soft iron, were coiled two lengths of insulated wire, in such a way that each coil occupied its own separate half of the ring, Fig. 840. Now, by sending a voltaic current through one of these coils, as A, the whole ring could be polarized, not so as to exhibit magnetism, but to form a closed magnetic circuit, like that of a horse-shoe magnet with its armature on. By stopping or reversing the current, the polarity of the ring was of course destroyed or reversed. Now, at every such change a momentary current flowed through the other coil B, though neither connected with the battery, nor so situated as to have secondary currents induced in it by the coil A.

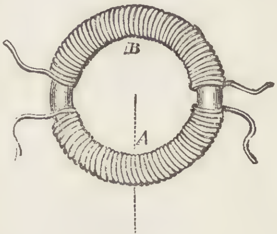


Fig. 840.

The same effects are produced if the ring consists of two halves, and without interrupting the primary current or demagnetizing A, whose magnetism is in this case manifest, we simply detach it from B, or replace it. It only remains then to dispense with the battery, and to polarize and depolarize the iron B by magnetic induction alone. Thus, suppose A with its coil to be removed, and its place supplied by a permanent steel magnet; by alternately removing and replacing it, the soft iron semicircle B will, at each change in its state, induce a momentary current through the surrounding coil; and the same effects will be doubled if we turn the magnet round on the dotted line as an axis, so as to present alternately different poles, and thus constantly reverse those of the soft iron.

These effects are still further exalted by alternately interrupting the circuit of the coil B, precisely at the moments when the iron is depolarized, so as to take advantage of the secondary current. These breaks are easily effected by a little wheel fixed on the same axis as the magnet, or the armature B, for it matters not which is made to revolve, and by nicely timing these motions, the spark, the shock, and all the other effects of electricity are produced, and the contrivance constitutes a *magneto-electric machine*, one form of which (Saxton's) is shown in Fig. 841.

A A is the magnetic battery composed of several thin layers of steel, which being separately magnetized to saturation, give a much greater power than a solid horse-shoe of the same thickness. B B is the middle portion of the armature, whose ends are turned at right angles towards those of the magnet (which they

(1) Of all forms of electricity, these secondary currents are the most remarkable for their physiological effects. By rapidly breaking and renewing the primary current by a toothed wheel, against which a spring presses, a rapid succession of shocks is produced, which, when received through metallic handles, cause an involuntary muscular contraction, rendering it impossible to relinquish the grasp. When received from water, they are more endurable, though even in that case we have seen strong men trying in vain to pick up coins placed only two or three inches below the surface

nearly touch), and are covered with two coils containing together from 50 to 800 yards of insulated wire. One end of this wire communicates with the axle *d d* on which the armature is fixed, and which is rapidly turned by the band passing over the wheel E. The other end of the wire is connected with the hollow cylinder *f* which surrounds the axle, but is insulated from it. A spring *g* constantly presses against this cylinder, and communicates with the plate *h*, which is one of the electric poles of the machine. The other

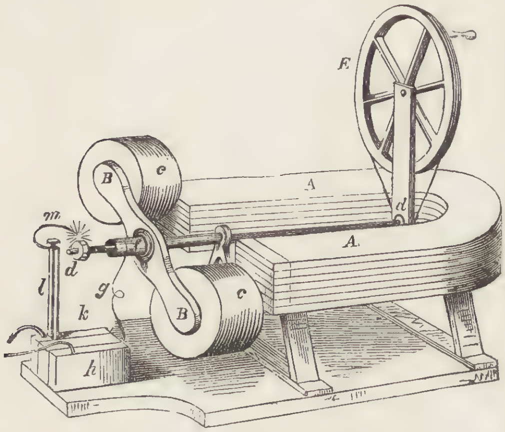


Fig. 841. MAGNETO-ELECTRIC MACHINE.

pole, *k*, (insulated from *h*,) communicates by the pillar *l* and spring *m* with the little wheel *d*, called the *break*, the circumference of which is partly of metal and partly of wood or ivory,[1] so as to interrupt and renew, twice in each revolution, the metallic connexion between *m* and the axle. At every such interruption, (which occurs when the armature has just left the poles of the magnet,) a brilliant spark appears, provided the circuit be completed by joining *h* and *k*. This connexion may be made through the human body, or any apparatus by which the other effects of the current may be shown. These effects perfectly resemble those of the secondary voltaic current, and like them, seem to hold an intermediate place between those of tensional and of current electricity. Hence this machine is peculiarly instructive as supplying a link, which might otherwise seem wanting, between the common electrical machine and the voltaic battery, for it exhibits the chief properties of *both*, though in a degree far inferior to either.[2] This will be understood by remembering that in tensional electricity the statical effects, or those of the *charge*, are continuous, and the dynamical, or those of the *discharge*, last only for an instant; while in voltaic batteries, on the contrary, the latter are continuous, and the former, if observable at all, are only momentary, viz. at the moment of breaking the circuit. But in the magnetic machine both the charge and discharge are only momentary, or of too short duration to be sensible, were it not for their rapid repetition. By turning the machine rapidly, wires may be kept at a red-heat, because they have not time to cool between the successive discharges.[3] As the current is *reciprocating*, it follows of course that in decomposing water by it, the gases are not separated, but a mixture of both is obtained from each pole alike. Hence, when the elements of an electrolyte are required separately, another form of break is employed by which every alternate spark is omitted, and the available power of the machine is reduced one-half. Yet such machines are found to furnish on a large scale a cheap supply of electricity for electro-plating and gilding, and their use for these purposes has been patented.[4] By combining several machines having all their armatures and breaks fixed on the same axis, but in different positions, an almost continuous current is kept up.

It will be observed that the effects of this machine are, strictly speaking, not due so much to the current induced directly by the magnet, as to the *secondary* current derived therefrom. But by other arrangements the *primary* magneto-current may be made sensible as a continuous current of extremely low tension. In fact, it has been established by Faraday that in general neither a magnet, nor any conducting body within its influence, can be moved without generating currents in one or both of them, provided a channel be open for their circulation; but they can only be detected by the galvanoscope. Their directions are always *across* the line of motion, and can be determined on the principles already explained. The magnet may be regarded as a natural machine which by some unknown mechanism converts *mechanical* into *electrical* motion, and *vice versâ*, and this in the peculiar way that a screw converts one mechanical motion into another, viz. rotation on an axis into progressive motion along that axis, and *vice versâ*. Thus we have seen that the insertion of a magnet into, or its withdrawal from, a helix or other cylinder generates currents round that cylinder;—*longitudinal* motion thus producing *rotatory* currents; and the converse of this is true; for the *rotation* of a magnet on its axis, or of

(1) There are many other forms of break, but this is mentioned as being one of the simplest.

(2) The most difficult effects to produce are those of statical attraction and repulsion. Yet, by nice arrangements, the gold-leaf electroscope has been affected. Leyden jars and batteries, however large, are charged by a single spark, but of course to no higher tension than that of the machine itself; and hence they afford none of the brilliant experiments which they do when charged by the frictional machine.

(3) The *quantity* of electricity passing in each discharge is proportional to the *size* of the wire forming the coils *c c*, but its *intensity* or *momentum* is proportional to the *length* of wire. Hence it is usual to employ for different purposes two distinct armatures, on one of which is coiled a *great length* of very *fine* wire, and on the other only a *moderate length* of much *stouter* wire. The former is used when the current has to penetrate bad conductors, as in giving shocks; but the latter when quantity is required, as for heating wires, or for showing the fusion and combustion of a metal point fixed on the end of the spring *m*.

(4) Ohm's theory teaches us that in using this machine for electrolysis, there must be for every different electrolyte a certain definite *length* of wire which will produce the greatest effect obtainable with a given *weight* of wire. Consequently, whatever may be the *size* of the wire, it should always have this *length*, which will depend on the conducting power of the electrolyte. For plating and gilding, a length of about 100 yards is employed, and in Woolrich's great machine the wire is $\frac{1}{16}$th of an inch thick. This affords a current equivalent to the separation of about 2 oz. of silver per hour, which is equal to 80 grains of water decomposed, or 800 cubic inches of gas produced. But for decomposing water (on account of its low conducting power) the proper length of wire would be greater.

other conductors round it, induces both in magnet and conductors *longitudinal* currents, which, if a conductor be supplied for their return, flow from the centre of the magnet to its ends, or else from its ends to its centre, according as the rotation is to the right or to the left. This is simply the reverse of that electro-magnetic experiment in which a metal cap or wire cage, poised on the top of an upright magnet, is made to revolve by a voltaic current passing up or down it. Instead of producing the rotation by a current, we may produce a current by the rotation; but this current will be in the contrary direction to that which would produce the same rotation. So also, all the common electro-magnetic experiments may be reversed and become magneto-electric ones, by substituting a galvanoscope for the battery, and then making the movable parts rotate by external force. Thus Saxton's machine may be regarded in this light as an inversion of Ritchie's revolving magnet,[1] Fig. 842, and the first magneto-electric currents detected by Faraday were those flowing along the radii of a copper disk revolving between the poles of a horse-shoe magnet, being an exact inversion of the revolving star experiment.

Fig. 842.

In all these cases the current induced by any motion is always such as would tend to produce the contrary motion.[2] Hence it is evident that every motion tending to induce magneto-electricity must encounter a certain mechanical resistance apart from the common resistances of friction, air, &c., and proportional to the quantity of electricity disturbed. In Saxton's machine this resistance is at once referred to the mere attraction of the magnet for the armature; but in fact all magnetic attraction is only a particular form of this resistance. It often assumes other forms, some of which were observed by Arago before the discovery of magneto-electricity. He found that oscillating magnets were brought to rest sooner in the neighbourhood of masses of copper or other electrical conductors, than in their absence; and that if both the magnet and the copper were free to move, any motion of either of them dragged the other after it, though all effect of the air was excluded by interposing plates of glass. Magnets and copper discs of many pounds weight were made to revolve in this way; and a small piece of copper suspended by a thread between the poles of Faraday's great electro-magnet, and spinning rapidly by the untwisting of the thread, is *instantly arrested* in a striking manner, the moment that a mass of iron is polarized. These effects are common to all good electrical conductors, however destitute they may be of magnetism properly so called, *i. e.* of action on the magnet when *at rest.*

Even in the common galvanometer every mechanical displacement of the needle induces a current round the coils. Whenever its north pole is moving *eastward*, a current flows in such a direction as would tend to deflect it *westward*, and *vice versâ.* Hence the reaction of these currents on the needle tends to bring it to rest, or to retard all its motions, and thus a galvanometric coil, or still better, a solid mass of copper of the same form, surrounding the needle, as in Fig. 843, tends to check or steady its vibrations, and is used for this purpose in magnetic observatories. An excellent form of compass has been contrived by Sir W. Snow Harris on this principle.

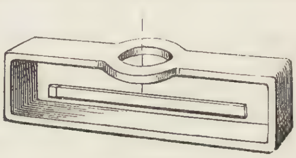


Fig. 843.

Even the currents induced by the earth's magnetism may be rendered sensible thus. If a helix, the ends of which are connected with a galvanoscope, be placed with its axis in the position of the dipping needle, the sudden insertion or removal of a core of common iron will cause momentary currents to circulate through the helix, because the iron becomes a magnet the moment it is placed in this position. The same effects will ensue if without removing the core, which should be of very soft iron, we turn both it and the helix (which must be connected with the galvanoscope by *flexible* wires) end for end, for by this action the poles of the soft iron are reversed. Here, however, the earth only acts mediately through the iron, and is not shown to induce electricity, but only magnetism; but the last experiment will succeed, although in an inferior degree, with an empty helix, thus proving the direct action of the earth in inducing currents, just like any other magnet.

Again, if a disc of copper be made to revolve horizontally over a magnetic pole, currents will tend to flow either from the centre of the disc to its edges or

(1) This is the general form of this instructive apparatus. N S are the two poles of a horse-shoe magnet: *a b* is a wooden cup for mercury, divided into two parts, *a* and *b*: *a* is connected by a wire with one end of a small single-cell galvanic battery, and *b* with the other end. *c* is the electro-magnet, consisting of a small bar of soft iron, surrounded at its ends with a continuous coil of stout copper wire, the two terminations of the wire dipping into the mercury. The polarity of either end will vary according to the termination of the wire which may be in *b* or *a*. The electro-magnet is supported on a central vertical axis, which passes through a collar, and terminates in a point resting in a small agate cup, so that the electro-magnet is free to move in a horizontal plane. Now when the electro-magnet is placed at right angles to the line joining N and S, and the current gives one end, say X, a north polarity, the end X will be repelled by N and attracted by S: but the momentum acquired by the motion will carry it a little beyond the line of neutrality, and thus the wire dipping into the mercury *b* will pass over the partition into the mercury *a*: X will now be a south pole, and consequently will be repelled by S and attracted by N; but as soon as it gets to N, its momentum swings it over the partition into *b*, in which case it is repelled by N and attracted by S. The poles of the electro-magnet being thus reversed the moment the wires pass from one division of the mercury-cup into the other, a series of alternate attractions and repulsions between the poles of the electro-magnet and those of the magnet N S takes place, and thus the former, being free to move, rotates with great rapidity.

(2) This is a general rule applicable to the actions between currents and currents, as well as between currents and magnets. For instance, two parallel currents flowing in the same direction attract each other; but the mutual approach of two parallel wires, only one of which is conducting a current, tends to induce a contrary current in the other wire. Again, two parallel and contrary currents repel each other; but the separation of two wires, only one of which conveys a current, will induce a current in the other wire in the same direction. Everywhere we meet with the same principle of action and reaction.

vice versâ, according as the rotation is to the right or left, because it may be regarded as forming part of the top of one of the revolving caps so well known in electro-magnetic experiments. To detect these currents, one wire of the galvanoscope is connected with the axle of the disc, or bearings, and the other with a spring that touches its edge. Now, when no magnet is brought near, the rotation still causes a current to pass, in the same direction as if there were a south pole presented below the disc; the fact being that there is such a pole, viz. the earth's north pole, which, we must remember, possesses the same properties as the south pole of a magnet. As this pole, however, is not directly under the disc, the latter should not, to produce the maximum effect, be quite horizontal, but dipping about 20° towards the south, so as to have its axis parallel with the dipping needle.

On these principles *Electro-telluric* machines have been constructed, for producing without magnets most of the effects of Saxton's machine, but in a lower degree.

ELEMI. A concrete resinous exudation, of which there are several varieties. The Gum Elemi of commerce is said to be furnished by *Amyris hexandra* of the West Indies. It is also said to be furnished by the *Canarium balsamiferum* of Ceylon, and by the *Icica icicariba* of the Brazils. It is imported in cylindrical cakes, covered with palm leaves; but, as it is scarce and costly, it is sometimes adulterated with common fir-tree resin. Its chief use is to form pastilles, or to burn as incense: it has been recommended as an ingredient in ointments, and also in some kinds of varnish. Fresh elemi is soft and viscid, but becomes hard and brittle by cold and by age; it is yellow, translucent, and of a peculiar odour, somewhat resembling fennel: it yields a volatile oil when distilled with water. It contains about 60 parts of an acid resin, soluble in cold alcohol, and 20 parts per cent. of an indifferent crystallizable resin soluble in hot alcohol. The composition of the former is $C_{40} H_{32} O_4$, of the latter $C_{40} H_{33} O$.

ELIQUATION. An old method of reducing ores of silver, now seldom resorted to. It consisted in fusing alloys of copper and silver with lead: this triple alloy was cast into round masses, which were set in a furnace upon an inclined plane of iron, with a small channel grooved out, and heated red hot: the lead melted out, and by its attraction for silver, carried that metal with it, and left the copper in a reddish-black spongy mass. See Silver—Assaying.

EMBANKMENT. See Drainage — Dyke — Railway.

EMBOSSING. The art of producing raised figures or patterns upon textile fabrics, paper, leather, &c., has already been brought under the reader's notice in the articles Calendering and Bookbinding. In the present article we propose to point out a few general applications of the art.

In the year 1824, the Society of Arts, London, rewarded Mr. J. Straker for a method of producing embossed designs on wood. Raised figures on wood, such as are employed in picture frames and other articles of ornamental cabinet work, are usually produced by carving, or by casting the pattern in plaster of Paris or other composition, and cementing or otherwise fixing it on the surface of the wood. The former method is expensive, and the latter not always applicable. Mr. Straker's invention, which may be used either by itself or in aid of carving, depends on the fact, that if a depression be made by a blunt instrument on the surface of wood, such depressed part will again rise to its original level by subsequent immersion in water. The wood to be ornamented having first been worked out to its proposed shape, is in a state to receive the drawing of the pattern; this being put in, a blunt steel tool, a burnisher, or a die is to be applied successively to all those parts of the pattern intended to be in relief, and at the same time is to be driven very cautiously, without breaking the grain of the wood, till the depth of the depression is equal to the subsequent prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which, the piece of wood being placed in water, hot or cold, the parts previously depressed will rise to their former height, and will thus form an embossed pattern, which may be finished by the usual operations of carving.[1]

In 1842 Mr. Baggaly patented certain improvements in making metallic dies and plates for embossing. The dies commonly used are produced by welding steel to the body of a wrought-iron block, and afterwards cutting or stamping the subject thereon. By the new method, the subject of the plate or die is produced from flat plates of steel, then cast in molten metal, and, lastly, soldered to cast-iron blocks. A model of the subject required to be sunk in the die being provided, a mould is made therefrom in plaster, sulphur, or other suitable material, and of nearly the same thickness in every part, the general figure of the back of the mould nearly corresponding to that of the face. From the back of this mould a cast-iron die or block is obtained in the usual way by means of a plaster model, of sufficient substance to bear the operation of stamping. From the face of the mould a model is obtained for casting a sinker containing the raised part of the subject in iron. This sinker must have a stud at its back for attaching it to the press or stamp hammer. The die-block and sinker having been adjusted in the press or stamp, a plate of steel or other suitable metal is heated to redness, and placed upon the face or upper surface of the cast-metal die-block; the sinker is then struck down upon the plate of steel, which, after several blows and repeated beatings, is brought into the form of the die-block on the under side, and of the sinker on the upper side. The steel plate is then trimmed, and hardened if required. It is then cleaned at the back and edges, and tinned over those parts. The face of the die-block is also cleaned and tinned, and the plate is then fixed by soft solder in the die-block, and pressed

(1) Transactions of the Society of Arts, vol. xlii.

whilst hot, so as to bring it firmly to its proper seat or bed. After this fixing it is " got up," *i.e.* worked upon by the tool, when it is ready for use.

Instead of sinking the figure of the dies out of flat plates, the figures may be produced in the face of the matrix or die by casting them from molten steel. Or, instead of steel, castings of malleable iron or brass and other alloys may be substituted.

Mr. Schroth has a patent for producing raised figures, or fac-simile copies of designs or patterns in leather or other similar material, such copies to be applied to all the purposes for which basso-relievo ornamental work is employed, such as the decoration of buildings and apartments, as medallions, cornices, panels, rosettes, picture frames, &c., and for cabinet work and other articles of furniture. The blocks or moulds, which are made of type metal and of fusible metal, are prepared from clay or plaster models of the objects to be copied; the leather is then forced into all the counter-sunk interstices of the mould in the following manner:—the skin is first beaten in water until it becomes properly softened and thickened; the operator then takes it out of the water, and rolls and works it with his hands, so as to make it shrink, that is, to increase its thickness at the expense of its width and length, after the manner of fulling. He then places it in the middle of the metal mould, and having ascertained the centre part of the design, he proceeds by gently unrolling the edges of the skin, and with the ends of his fingers presses it into the interstices of the die, stretching out the leather, and proceeding gradually from the centre to the edges. When the principal cavities are filled, the leather is pressed into the smaller ones by means of a wooden, bone, or copper tool, similar to that used in modelling, making use also of a brush, with which the skin is gently struck. A sponge is also pressed down for the purpose of absorbing the water. When properly filled in, the leather may be dried and finished by heat; the mould containing the skin is to be placed on a chafing-dish until the temperature of about 108° to 144° Fahr. is attained. During the drying, papier-maché or other suitable material is forced into the deepest cavities of the skin, to prevent it from receding from the die; the preparing tool and sponge must also be used repeatedly for the same purpose. The elasticity of the leather and its contraction in drying, will allow it to be drawn out of the deep and counter-sunk parts of the mould.

A second method of compressing and drying is by employing an absorbent substance in powder, such as well-dried sawdust, in which case the mould, with the skin forced into it, is placed in the bed of a press, and enclosed in a frame of wood or metal, formed of side pieces, without top or bottom; the top edges of the frame being about two or three inches higher than the mould when the design is not much in relief, and from about six to twelve inches or more when the embossing is raised to a greater degree. This frame being filled with sawdust, a plate, or follower, is placed above the frame, of such a size as to enter it freely. The screw of the press being turned, the compression of the sawdust forces the leather into all the cavities of the mould. After some time the mould may be taken out, and dried by heat or in the open air, according to circumstances. The cavities in the back of these embossed figures must be filled up with paper, sawdust, pulverized cork, mixed with glue or hot resin. The face may be painted, gilt, or silvered, if previously rendered impervious by gum-lac or any suitable resinous substance.[1]

EMBOSSING-PRESS. Figs. 844 and 845 represent two views of a highly ingenious and beautiful machine, designed and constructed by Mr. Edwin Hill, for the purpose of impressing the medallion stamp upon the postage envelopes. Several of these presses have been in use at Somerset House during the last eleven years.

Other machines, invented by Sir William Congreve for stamping tickets relative to the post-horse duties, were, on the introduction of the post-office envelopes, used for embossing these medallion heads, for which purpose they were modified by Mr. Hill. In these machines the blow was given by a falling weight; but the construction did not admit of a high quality of embossing, and there were other objections to the Congreve machines: Mr. Hill, therefore, invented a new press, in which greater precision, finish, and rapidity of execution were attained by the introduction of the principle of the fly-and-screw press. The difficulties to be overcome were, 1. To accomplish the whole operation of embossing and printing the coloured ground entirely by the machine, the ordinary plan being to ink the die by hand; and, 2. To perform the operation with such rapidity as to keep down the expense to an exceedingly low scale; for, the postage stamps being used mostly in the collection of so low a duty as one penny to each stamp, it is obvious that any sensible cost of production would absorb an important fraction of the postage revenue.

The machine consists of a strong fly-and-screw press, with an inking apparatus, including a peculiar contrivance for accelerating the rate of stamping, without accelerating the angular motion of the fly and screw. The envelope is placed under the stamp by an attendant at the precise moment when the stamp is being inked; the position of the envelope being determined by guides, so that the impression may be in the same place in all the envelopes. When the die descends and makes the impression, it immediately rises again preparatory to another blow: a second attendant removes the stamped envelope, and the first attendant puts a blank envelope in its place. So rapidly are these motions performed, that a blank envelope is placed under the die, stamped, and removed, sixty times a minute; and so dexterous do the two attendant boys become, that, while feeding the press, they are also engaged in reading out of an open book placed in a convenient position before them.

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(1) Newton's London Journal of Arts and Sciences, &c. vol. xxii. 1843. The reader interested in this subject will find in this volume directions for making the moulds in an economic manner. The date of Mr. Schroth's patent is 26 June, 1839.

We will now describe the working parts of the press. The main spindle is driven by a strap, at the rate of one turn of the machine per second; each turn producing an embossed medallion stamp. From the main spindle, motion is communicated *first* to the fly and screw, which of course rise and fall alternately, and *secondly*, to the bolt of the press, at the lower end of which the die is attached. In the *third* place, motion is communicated to a very strong steel punch or drift, which, at the moment when the blow is given, is interposed between the end of the descending screw and the head of the bolt, thus transmitting the force from the screw to the bolt. When the impression is completed, this punch is withdrawn, and the bolt ascends, in order that the die may receive its supply of ink. *Fourthly*, motion is given to the inking apparatus, which consists of a ductor, an inverted inking-table, and a sliding frame, carrying the four composition rollers. The machine, when in motion, can be stopped by means of an apparatus so constructed that when pressed down, the principal cam, upon arriving at a certain point of its revolution, is at once arrested. It is necessary to stop the machine in one particular position, so as to allow the dies and the inking apparatus to be readily got at.

The different members of the machine are shown in Figs. 844 and 845, the views of the same parts being indicated by the same letters in both engravings. A A is the main spindle, and S the driving-strap; *c* and *c'* are two cranks, one at each end of the main

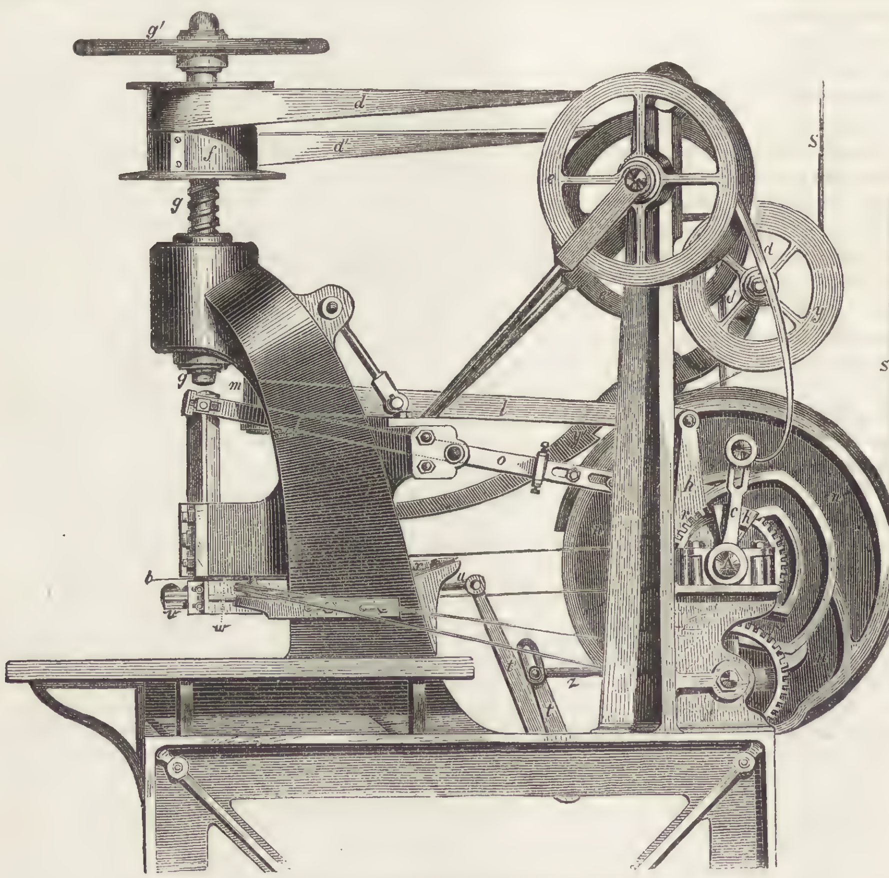


Fig. 844. ELEVATION OF EMBOSSING-PRESS.

spindle, which, by means of the two straps *d* and *d'*, passing over the pulleys *e* and *e'*, and attached to the drum *f*, which is fixed upon the screw *g*, turn the screw, together with its fly *g'*, backwards and forwards alternately, producing thereby its alternate rise and fall. These two cranks, however, are not made fast upon the main spindle, but are operated upon, each at its proper time, by two other cranks *h* and *h'*, fixed to the main spindle. This provision of loose and fast cranks is rendered necessary by the rebound of the screw and fly from the blow, which outruns the cranks, and would break the straps but for this precaution. Upon the main spindle is a cam *i*, which moves the lever *k* backwards and forwards, and, through the horizontal bar *l*, the punch *m* is also moved backwards and forwards, and thus interposed between the screw *g*, as it descends, and the bolt *b*, at the moment when the blow is given: *n* is a second cam upon the main spindle A A, which, by alternately raising and depressing the levers *o o*, raises and depresses the bolt *b*, to the lower end of which the die is attached: *r* and *r'* are toothed wheels, for driving the inking apparatus; *r'* has a crank-pin, which, by means of the link *z*, sways backwards and forwards the arm *t*, and through that the arm *t'*, fixed upon the same spindle. This last arm *t'*, through the link *u*, draws backwards and forwards the inking-frame

o, with its four composition rollers, which ink the die by running under it when the bolt is in its raised position, as shown in the figure. *w* is the inverted ink-distributing table: it is circular, and is acted upon by a slack band, which turns it round feebly whenever the inking-rollers lose contact with it. *x* is the doctor, furnished with a roller which is constantly turned round by a band: *y* is a slacking pulley fixed to the arm *y'*, on which arm is also a break which binds against the main driving-wheel, and a strong tooth, catching a projection on that wheel, and bringing the machine to a dead stop always in the same position, *i.e.* nearly in the position shown in Fig. 844.

Similar machines have lately been constructed for the use of the Prussian and Neapolitan governments, and for the East India Company. These presses are also used in the manufacture of embossed wafers.

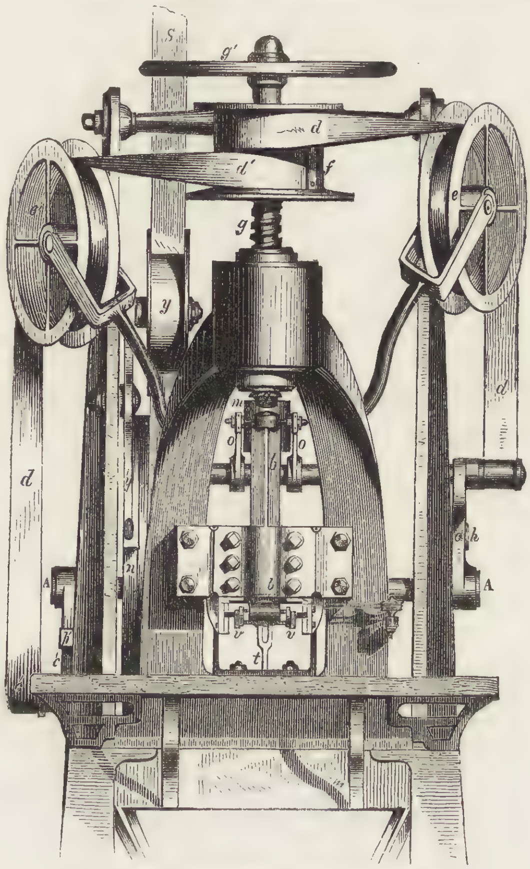


Fig. 845. END ELEVATION OF EMBOSSING-PRESS.

EMBROIDERY is an ancient art, as we find from the mention made of it both by sacred and profane writers. From a very early period, people knew how to embroider stuffs and vary their colours, either by means of the needle, working into a plain ground threads of different colours, gold, or precious stones, or by introducing such threads into the tissue of the stuff while preparing the warp. The directions for making the Tabernacle and its embroidered curtain show the knowledge of this art communicated to the Hebrews. (Exod. xxvi. 1—31; xxxix. 2, 3, 5, 8, &c.)

The Medes and Babylonians of ancient times were celebrated for the beauty of the draperies of their apartments. The hangings which decorated their palaces were wrought by the needle, which in eastern nations is still employed in embroidered works. Chardin says of the Persians,—"Their tailors certainly excel ours in their sewing. They make carpets, cushions, veils for doors, and other pieces of furniture of felt, in Mosaic work, which represents just what they please. This is done so neatly, that a man might suppose the figures were painted instead of being a kind of inlaid work. Look as close as you will the joining cannot be seen." Tents, which are so much used in hot countries among Nomadic tribes or on military excursions, have for ages kept the skill of the eastern embroiderer in practice. The covering of tents among the Arabs is usually black goat's-hair, so compactly woven as to be impervious to rain. In addition to this, there is usually an inner tent of white woollen stuff, on which flowers are embroidered. Curious hangings are also hung over the entrances. A tent of a late king of Persia, which is said to have cost 2,000,000*l*., and to have been a load for forty camels, "was embroidered with burnished gold, studded with precious stones and diamonds, interspersed with rubies and emeralds set with rows of pearls; and there was painted thereon a specimen of every created

thing, birds, and trees, and towns, cities, seas, and continents, beasts and reptiles."

This art was also generally known among other Asiatic nations. Homer speaks of embroidery as the occupation of Helen and of Andromache; he mentions also the golden cincture of Calypso, and that of Circe. At that period, (unless the poet's imagination has rendered his description too partial,) embroidery approached painting in the truthfulness of its imitations: in Ovid's fable of Minerva and Arachne, the art is praised as giving the touches of light with a degree of fidelity beyond that of painting, but which they were enabled successfully to accomplish in wool. Many modern authors are, indeed, disposed to seek the origin of painting among the Greeks in the talent of the Ionian women in tapestry-work. We find even, in the Memoirs of the Academy of Sciences, an interesting dissertation on Painting, in which the author, describing the numerous varieties of that art, makes mention among them of tapestry worked with the needle or at the loom, and of designs executed on white silk and cotton cloth, by employing various dyes which penetrate the stuff.

At the present day the most patient and laborious embroiderers are said to be the Chinese; their regularity and neatness are very great, and the extreme care with which they work preserves their shades bright and shining. The Indians also excel in this kind of work. "They embroider with cotton on muslin, but they employ on gauze, rushes, skins of insects, nails and claws of animals, walnuts and dry fruits, and, above all, the feathers of birds. They mingle their colours without harmony as without taste; it is only a species of wild mosaic, which announces no plan and represents no object. The women of the wandering tribes of Persia weave those rich carpets, which are called Turkey carpets from the place of their immediate importation. But this country was formerly celebrated for magnificent embroideries, and also for tapestries, composed of silk and wool, embellished with gold. This rather beautiful art, though not entirely lost, is nearly so, for want of encouragement. But of all Eastern nations the Moguls were the most celebrated for their splendid embroideries; walls, couches, and even floors, were covered with silk or cotton fabrics, richly worked with gold, and often, as in ancient times, with gems inwrought." [1]

The poet Cowper has immortalized Mrs. Montague's feather hangings. Various articles of dress have of late years been covered or ornamented with feathers, such as muffs, tippets, &c. In Canada, the women embroider with their own hair and that of animals, copying the ramifications of moss agates and of plants; they also insinuate into their works skins of serpents and morsels of fur, patiently smoothed. The Negresses of Senegal embroider various skins of animals with flowers and figures of all colours. The Turks and Georgians embroider the lightest gauze or crape; they use a very delicate gold thread, and represent very minute objects on morocco without varying the form or fraying the gold. They have a habit of ornamenting their embroidery with pieces of money of different nations, and travellers often find in their old garments valuable and interesting coins.

In Saxony, embroidery is practised on muslin with untwisted thread, and is very beautiful. That of Venice and Milan is celebrated, but costly. France has also a reputation for embroidery; but the Germans, especially those of Vienna, are said to be most successful in the art. In England, as Mrs. Stone remarks, the practice of ornamental needlework and of embroidery have gradually declined from the days of Elizabeth. "The literary and scholastic pursuits which in her day had suspended the use of the needle did not, indeed, continue the fashion of later times; still the needle was not resumed, nor perhaps has embroidery and tapestry ever, from the days of Elizabeth, been so much practised as it is now."

Embroidery at the present day is not merely a female occupation, but a considerable branch of industry, which occupies thousands of young persons and children, and makes large demands not only on the manual dexterity, but on the intelligence of those who practise it; for the work of the embroiderer requires that he should understand the nature of the materials with which he deals, their several aptitudes to take certain dyes, and to bear certain processes. It requires also a knowledge of drawing, and of the proper arrangement of colours, with inventive power to produce novelties, and methods of executing them in a tasteful and economical manner.

The practice of tapestry-weaving with a shuttle was originally done in a standing posture; the threads of wool being stretched perpendicularly, and not, as they are now, wound upon a beam. The warp was confined by a piece of wood, to which heavy weights were attached. The Egyptians were the first, according to Pliny, who changed the old and inconvenient method, and introduced the custom of sitting to the work, as is now done by the workmen in the royal manufacture of the Gobelins, of Beauvais, Aubusson, &c. The same author informs us that when embroidered materials were old and worn, the ancients were accustomed to transfer the worked parts to a new ground, and thus to give them a prolonged existence. Thus the embroidery was cut out, following the contours of the original design, and then applied, laid on, and sewed upon a plain ground of a different colour. This was a common practice in trimming the robes of Roman matrons, and is what is meant by Ovid and Horace when they speak of such robes being embroidered or bordered with a fringe of purple, &c. The sort of trimming among the Romans, frequently expressed the dignity, sex, and age of the wearer.

The practice of embroidery varies with the nature of the materials worked with. In embroidering stuffs the work is performed in a stretching-frame. Muslin is starched, and then spread out upon a pattern; while working the flowers, it is necessary to count the threads of the muslin both in the warp and in the

(1) The Art of Needle-Work from the Earliest Ages, by Elizabeth Stone. Edited by the Right Honourable the Countess of Wilton. Third edition. London: 1841.

weft. This makes the work tedious, but it is richer in points, and susceptible of greater variety, than when done at the stretching-frame. Cloths too much milled are not well adapted to this kind of ornament.

In the practice of embroidery, the French divide the art into various classes. The first class is called *white* embroidery, because it is executed on all kinds of white materials, with white cotton, flat, milled or twisted; with braid, edging, &c. This species of embroidery also comprehends—*festoon* embroidery, or that which consists of embroidering and cutting out the edge of the material to a certain pattern traced on paper or on the stuff itself. Festoon embroidery is also employed in the body of the work without cutting out. *Chain-stitch* embroidery, or that which traces the veins and general shape of the pattern in chain-stitch, and fills up the middle afterwards in a similar manner. *Needle-work* embroidery, or simple horizontal stitches, each embracing as much of the material behind as before the thread, and applicable only to thin and soft materials, as muslin, cambric, &c. *Lace* embroidery on tulle, blonde, gauze, &c., manufactured by the aid of the Jacquard loom.

Proceeding from these works in a white material to the embroidery in colours, there are again many kinds. In one of these the figures are raised and rounded, by cotton or velvet, which is placed underneath to sustain them; in another, edging or lace is laid upon the design, and sewn on with thread of the same colour in various stitches; in another, the whole pattern is cut out in velvet or silk, and carefully sewn upon the material with thread or silk. Embroidery *en guipure* is a rich mixture of several kinds of embroidery, and may be executed in gold, silver, feathers, pearls, precious stones, &c. Embroidery in *flat tints* is when the threads and other coloured materials are simply put in juxtaposition; *shaded* embroidery is when the embroiderer seeks to follow nature closely, or to represent in its more delicate shadings the object, natural or artificial, which is to be imitated. Other names of embroidery are derived from the implements employed, as *crochet*, *loom*, or *tambour* embroidery. Under the name of embroidery are also comprehended the numerous kinds of work which consist in forming flowers upon all kinds of tissues, with ribbons or with coloured gauze.

The number of stitches in embroidery is strictly only two; the first embracing the material equally in height and width, and on both sides; the second executed either with a crochet or a common needle, and forming a continuous chain. Embroidery on canvas is distinguished from works in velvet, and from the different stitches for marking linen, and for making fancy articles with beads, &c. Embroidery on canvas is often called *tapestry-work*. The stitches, combined and arranged in various manners, represent the desired figures, and take different names according to the countries where these combinations were first invented. Thus, there is *Berlin-stitch*, *French*, *Hungarian*, *English-stitch*, *Gobelins-stitch*, and many others.

Embroidery, as practised in England, comprehends: 1. Embroidery *on the stamp*, where the figures are raised, and rounded by means of cotton or parchment beneath. 2. *Low* embroidery, where the gold and silver lie low upon the sketch, and are stitched with silk of the same colour. 3. *Guimped* embroidery, which is performed either in gold or silver. A sketch is first made upon the cloth, then put on cut vellum, and afterwards sewed on the gold and silver with silk thread; and on this kind of embroidery are often added gold and silver cord, tinsel, and spangles. 4. Embroidery on both sides of the stuff. 5. *Plain* embroidery, which is flat and even, without cords, spangles, or other ornaments.

The elements of tapestry-work are five; namely, the *design* which the embroiderer is to imitate; the dyed *threads* of wool or silk, variously and properly sorted; the *canvas*, more or less regular, of which the interlacing threads guide the stitch; the *frame* on which the canvas is conveniently stretched; the *needle*, with a large head and a blunt point, which serves to pass the coloured thread freely through the squares or meshes of the canvas. A correct drawing of the object to be reproduced upon the canvas must be constantly under the eye of the embroiderer. Some of these designs are engraved, printed, and coloured upon paper representing canvas, so that the forms and colours exactly fill the corresponding squares to those on which the stitches are to be set. Others are traced upon the canvas itself in outline, or without coloured shadows: in this last case, the embroiderer works according to her taste, and according to the nature of the objects, in arranging the coloured threads, and in putting in the lights and shadows. Tapestry itself, bought ready-made, very often serves for a model, which is imitated on the corresponding part of the canvas, by counting successively with a pin the stitches in such and such a shade of the model, and the squares of the canvas which must receive them; but this, of course, takes more time than working from a design traced on the canvas.

There is also an invention for taking patterns from lithographic drawings, which serves the purpose of embroiderers, especially of such as would imitate the famous Gobelins tapestry. A sheet of thin paper-canvas, or paper on which the meshes of canvas are accurately represented, is applied to a lithographic drawing, and secured to it with soft wax. The design is then copied through the transparent paper-canvas, of which the number of squares, previously reckoned so as to determine the dimensions of the design, shall determine the number of stitches, and the colours which must be employed.

Several kinds of embroidering frame are in use, but one of the most easy to manage is made with a system of iron hooks fixed upon the cross pieces of the frame, and serving to stretch the canvas on the two opposite sides. This sort of frame is now but little used, on account of the price of its construction. The working embroiderers prefer the screw or the lath frames, which are sold at a cheaper rate, and admit of more easy adjustment. But in the lath-frame the material is often stretched too much or too little, and thus is inferior to the screw-frame, in which

the stuff can be stretched little or much, according to the wish of the worker. Most of the frames in use have the disadvantage of obliging the embroiderer to sew the two sides of the canvas upon the galloon nailed upon the two rollers, then to roll up the canvas, and fix it to the sides by means of packthread, which is liable to distend it too much, and tear it. Improved frames have been introduced, in which the canvas is secured by blunt points attached to the sides, and covered with a wooden bar, cut half-round, and having along its length a slit or groove of a width corresponding with the points. The sides of the frame are secured and the canvas properly stretched

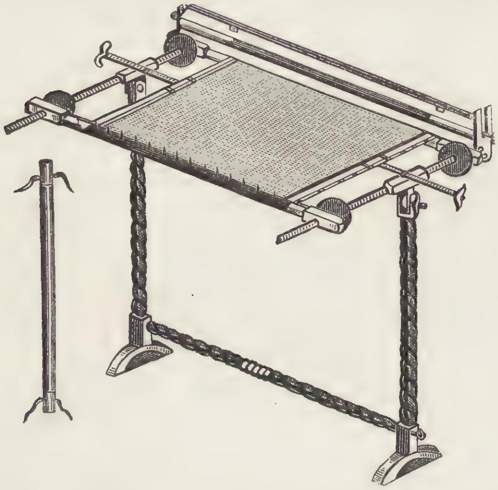


Fig. 846. HAND EMBROIDERING FRAME.

by means of screws. One of these improved frames is shown in Fig. 846.

EMBROIDERING MACHINE. As most mechanical processes which have hitherto been performed by hand, can be much better accomplished by a machine, so the refined art of the embroiderer has yielded to the skill of the engineer. In the French Industrial Exposition of 1834, M. Heilmann of Mulhousen exhibited an embroidering machine which enables a female to embroider a design with 80 or 140 needles as accurately, and nearly as expeditiously, as she formerly could with one.

The principle of this ingenious machine is as follows:—the piece of cloth to be embroidered is suspended in a vertical position. The needles with which the ornamental work is performed are not like ordinary needles, with an eye at one end and a point at the other, but are furnished with a point at each end, and the eye in the middle, as shown at V′, Fig. 849; these needles are held by pincers in a frame, and the piece of cloth which is to be embroidered being suspended in a vertical position, the carriage containing the needles is wheeled up to it; all the needles pierce it, and on passing through a certain distance, are seized on the other side by the pincers of a second frame. On drawing this frame away from the fabric, it is evident that the needles must be completely drawn through, together with the threads inserted in them; and on sending the second frame up to the cloth, the needles will be passed through in an opposite direction, and be clipped and drawn through by the first frame. During these motions of the two frames backwards and forwards, the frame in which the cloth is suspended is moved by an attendant in a regulated order, by means of a lever attached to a pantograph; so that, as the attendant goes regularly over the points of a pattern, drawn on a large scale at the side, the cloth is slightly shifted at each motion, and the pattern is repeated thereon, on a small scale, by the passage of the needles.

This machine may be described under four heads. 1. The structure of the frame. 2. The arrangement of the web. 3. The arrangement of the carriages. 4. The construction of the pincers. A front view of this machine is shown in a separate steel engraving.

1. The frame is composed of cast-iron, and is massive. The length of the machine depends upon the number of pincers to be worked. The machine at the French Exposition had 130 needles, and consequently 260 pincers arranged in two rows, an upper and a lower row; its length was $2\frac{1}{2}$ metres, or about 8 feet 4 inches. The breadth of the frame must not be less than about 40 inches. It is usually the same in all machines, and determines the length of thread to be put into the needles.

2. The piece to be embroidered is strained perpendicularly upon a rectangular frame, of which the vertical sides F F are shown in the steel engraving, and the horizontal sides F′F′. The piece to be embroidered is wound upon two rollers G G, whose ends, mounted with iron studs, are supported upon the sides F of the frame so as to turn freely; small ratchet wheels g' g' at the ends of these beams allow the piece to be stretched between them. (See Fig. 847.) There are also two central beams furnished with ratchet wheels g g at their extremities. As it will be seen by Fig. 847 that the two beams are not in the same vertical plane, the plane of the web would be presented obliquely to the needles, were it not for a straight bar of iron G′ G′, round the edges of which the cloth passes, and is thus made vertical. The two upper rollers present the web to the upper row of needles, and the two lower rollers present it to the lower row of needles. The piece is kept stretched crosswise by small brass templets, to which the strings y' are attached, and by which it is pulled towards the sides of the frame F. The pantograph for shifting the web into all the required posi-

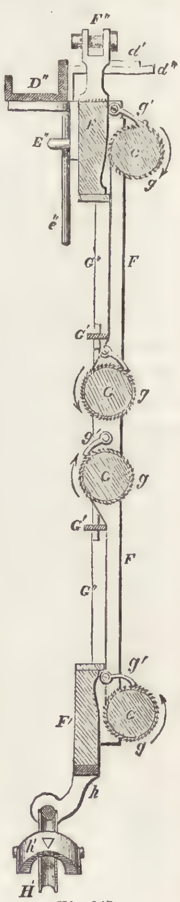
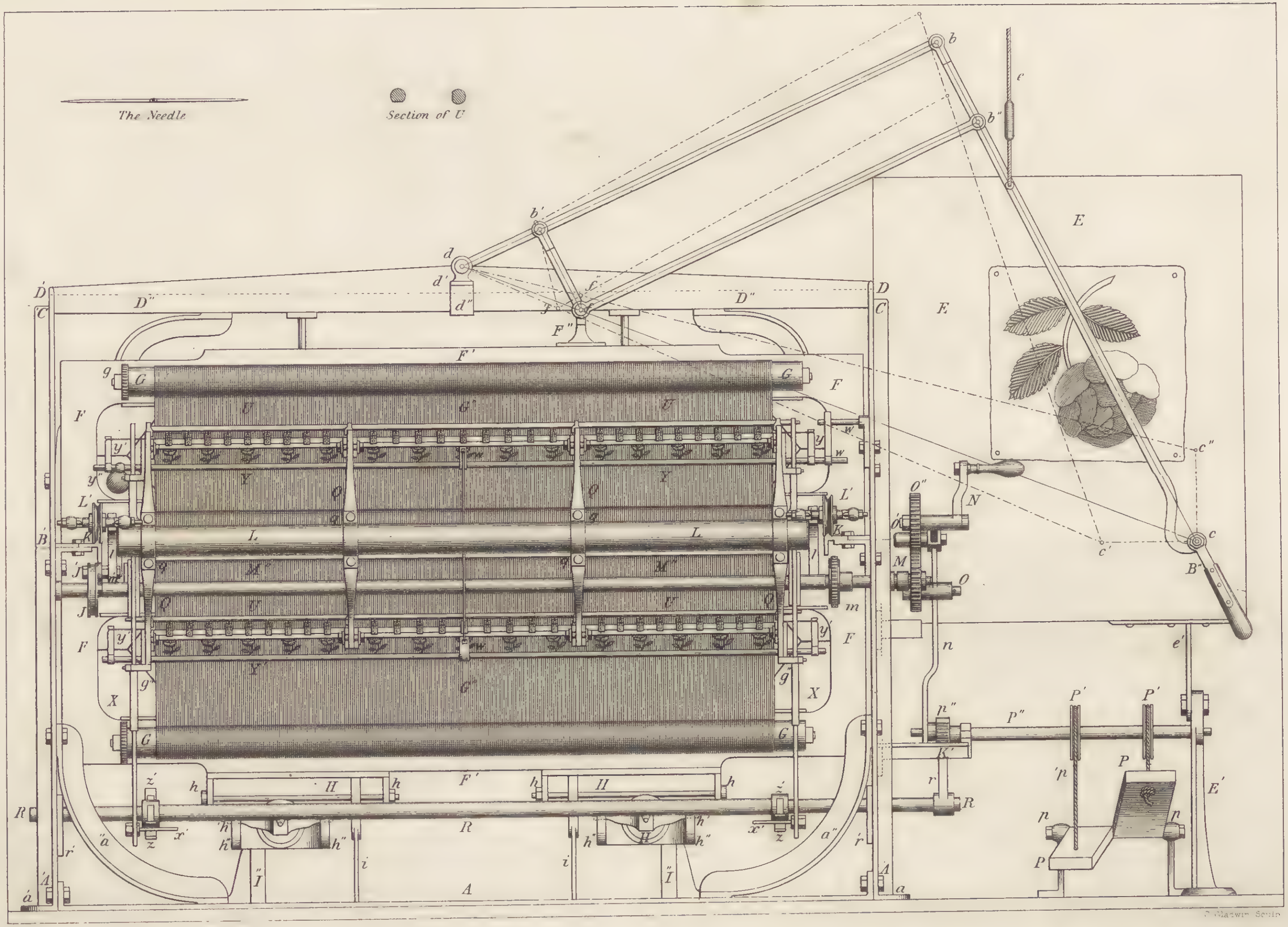


Fig. 847.



EMBROIDERING FRAME INVENTED BY M. HEILMANN OF MULHAUSEN.

tions is arranged in the following manner:—$b\,b'\,f\,b''$ is a parallelogram, the four angles of which are jointed in such a way as to be made very acute or very obtuse at pleasure, while the sides remain of the same length; the sides $b\,b'$ and $b\,b''$ are prolonged, the one to the point *d*, and the other to the point *c*, and these points *c* and *d* are chosen under the condition that in one of the positions of the parallelogram the line *c d* which joins them, passes through the point *f;* this condition may be fulfilled in an infinite variety of ways, since the position of the parallelogram remaining the same, it is evident that if we wish to shift the point *d* further from the point b', it would be sufficient to bring the point *c* nearer to b'', or *vice versâ;* but having once fixed upon the distance $b'\,d$, it is clear that the distance $b''\,c$ is its necessary consequence. Now, the principle upon which the construction of the pantograph rests is this: it is sufficient that the three points *d*, *f*, and *c* be in a straight line in one only of the positions of the parallelogram, in order that they shall remain always in a straight line in every position that can be given to it. If the side $b\,b''$ has been made equal to the sixth part of *b c*, $f\,f'$ will also be one-sixth of *c c;* that is to say, the lines described by the point *f* will be exactly the sixth part of those described by the point *c*. [See PANTOGRAPH.]

The side *b c* is furnished with a handle B$''$, with which the workman moves the suspended web into the positions required. In order that this may be done with precision, the sides of the pantograph are joined so that the middle of their thickness lies exactly in the vertical plane of the web, and that the axes of the joints are truly perpendicular to this plane, in which, consequently, all the displacements are effected. This result is attained by making fast to the superior great cross bar D$''$ an elbow piece d'', with a projection to which is adapted in its turn the piece d', which receives in a socket the extremity of the side *d b;* this piece d' is made fast to d'' by a bolt, but it carries an oblong hole, and before screwing up the nut, the web is made to advance or recede till the fulcrum point comes exactly into the plane of the web. The frame is then attached to the angle *f* of the parallelogram by means of the piece F$''$. (See Fig. 847.)

Now, if the workman take the handle B$''$ in his hand, and make the pantograph move in any direction, the point *f* will describe a figure similar to that described by the point *c*, but six times smaller; but the point *f* cannot move without the frame and the web mounted upon it moving also. Thus, in the movement of the pantograph, every point of the web describes a figure exactly similar to that described by the point *f*, and consequently similar to that described by the point *c*, but six times smaller; the embroidered object being produced upon the cloth in the inverse position of that of the pattern. It is, therefore, sufficient to give the man who holds the handle B$''$ a design six times larger than that which is to be executed by the machine, and to afford him a sure and easy means of tracing over with the point *c* all the outlines of the pattern. For this purpose there is adapted to *c*, perpendicularly to the plane of the parallelogram, a small style terminated by a point; the pattern is fixed upon a vertical tablet E, parallel to the plane of the stuff and of the parallelogram, and distant from it only by the length of the style: this tablet is carried by the iron rod e' secured to a cast-iron foot E$'$. The frame, loaded with its beams and cloth, is very heavy; and as it must not be allowed to swerve from its plane, it must be lightened so as to enable the operator to cause the point of the pantograph behind *c* to pass along the tablet without any straining or uncertainty in its movements. For this purpose, a cord *e*, attached to the side *b c* of the pantograph, passes over a return pulley, and carries at its extremity a graduated weight, which equipoises the pantograph, and tends slightly to raise the frame. The upper part F$'$ of the framework carries two projecting rods E$''$ (see also Fig. 847), furnished with a longitudinal slit, in which the bolt e'', moving with slight friction, also serves as a guide to keep in its place the upper part of the frame. The lower part of the frame carries two horizontal rods H H, each attached by two arms *h h*, bent a little on one side, both of which are engaged in the grooves of a pulley H$'$. (See the engraved plate, and also Fig. 847.) By means of this mechanism, a regulated pressure can be exerted upon the frame from below upwards; and without preventing the frame from moving in all directions, it hinders it from deviating from the primitive plane to which the pantograph was adjusted. The lengths of the rods H ought to be equal to the amount of the lateral movement of the frame. Two guides *i i*, supported by two legs of cast-iron, present vertical slits in which the lower part of the frame F is engaged.

3. The two carriages, one on each side of the web, are similar. (See Fig. 850.) Each carriage is a long hollow cylinder of cast-iron L, carrying at either end two grooved castors or pulleys L$'$, which roll upon the horizontal rails K; the pulleys are mounted upon a forked piece l', with two ends to receive the axis of the pulleys, and the piece l' itself is bolted to a projecting ear *l*, cast upon the cylinder. (See Fig. 849.) Thus each carriage rests in stable equilibrium upon the rails K, and may be easily moved backwards and forwards, so as to pass or draw the needles through the cloth. Each carriage is usually moved by its own attendant; but the man who works the pantograph can, by turning the handle N in one or other direction, cause the carriage to approach to, or recede from the web. For this purpose a pulley J is attached to the uprights A C, A$'$B$'$, only one of which is shown on the side A$'$ B$'$, it being omitted on the side A C in order to show the toothed wheel *m*. At the height of the pulleys J is an axis M$''$, bearing towards each of its extremities a toothed wheel *m;* this axis is prolonged on the left side for the purpose of carrying another toothed wheel M. Upon the pulley J, and on the toothed wheel *m*, corresponding thereto, is an endless chain so arranged that on turning the axis M$''$ in one direction, the carriage is brought up to the web, and in turning it in the other direction, it is removed therefrom.

When one carriage has advanced so as to pass the needles into the stuff, the other carriage is present to

receive them; it seizes the needles with its pincers, pulls them through, and then withdraws in order to stretch the thread and close the stitch: it then goes back with the needles and inserts them into the web in its turn. During these movements the first carriage remains at its post, waiting the return of the second, so that the two carriages make in succession an advance and a return, but they never move together. To produce these movements there is attached to the piece O made fast to the two uprights A C and A D of the frame, a bent lever, *n* O, movable round the point O, and carrying the toothed wheels O′ O″; the four wheels M M′ O′ O″, have the same number of teeth, and the same diameter; the two wheels O′ O″ are so fixed that on turning the handle N the wheel O″ revolves, and consequently the wheel O′; when the lever *n* O is vertical, the wheel O′ touches neither the wheel M nor the wheel M′; but if it be inclined to one side or the other, it brings the wheel O′ alternately into gear with M or M′. As the man has both hands occupied, the one with the pantograph and the other with the handle N, his feet are employed for acting on the lever *n* O, for which purpose two pedals are provided, and thus he performs with his feet a series of operations no less delicate than those which he executes with his hands. The pedals P are movable round the axis *p*, and carry cords *p*′ wound in an opposite direction upon the pulleys P′, which are fixed upon a movable shaft P″, supported upon one side by the prop E′, and on the other in a piece K′ attached to the two great uprights of the frame. On depressing the pedal, which is shown raised in the figure, the upper part of the shaft P″ will turn from the left to the right, and the lever *n* O will become inclined so as to carry the wheel O′ upon the wheel M′; but, at the same time, the pedal which is now depressed will be raised, because its cord will be wound up upon its pulley as much as the other cord has been unwound; and thus the machine will be ready to act in the opposite direction when required to do so.

4. At regular intervals of about half a metre upon the shaft L, are the appendages *q q*, upon which are fixed by two bolts the curved branches Q, which carry the mechanism of the pincers, which will be understood from the following figures. T, Fig. 848, is the lower jaw of one of the pincers mounted on a prismatic bar S, and fixed thereto by a screw *t*. Above this screw a spring *t*′ serves to raise the hinder limb of the upper jaw V (shown detached in Fig. 848) and thus to force the short limb into contact with the lower jaw. About the middle are two small ears pierced with a hole, and separated from each other by an interval equal to the thickness of the upper jaw, and destined to receive the corresponding ear *v* of this jaw. A little to the right of the ears is a small vertical projection *t*″, whose function is to stop the needle, if from any cause it tends to advance too much. To the right is also a thin plate T′, pierced with a conical hole, larger outside than inside.

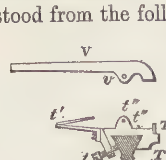


Fig. 848.

The lower jaw being in its place, the upper jaw is so arranged as to make it pass a pin traversing the three ears, in order to raise the pincers. The pincer is naturally closed by the operation of the spring *t*′, and it cannot be opened except in operating from above downwards upon the tail of the upper jaw V, with a pressure capable of overcoming the elasticity of the spring *t*′.

The needle is shown in the steel engraving, of the natural size, and also at V′ Fig. 849. It is pointed at both ends, and the eye is in the middle, as already stated. The silk thread is passed through it as in an ordinary needle, but is not doubled; the free end of the thread is unravelled, and then secured by being twisted by the action of the finger and thumb.

When a pincer is open, and one-half of the needle is inserted into the opening of the plate T′, it is then lodged in an angular groove, which is less deep than the needle is thick, so that when the pincers are closed, the upper jaw presses it into the groove, and the needle is firmly held, although touched at only three points of its circumference.

Suppose all the pincers to be mounted at proper distances, (varying with the kind of ornament on different webs,) in the prism S, and forming the upper range as in the steel engraving, the workman opens all the pincers at once to enable them to receive the needles which have been planted in the web by the opposite carriage. For this purpose an axis of iron U, a section of which is shown in the steel engraving, and in section Fig. 849, is supported by the forks *u*, at the extremity of the branches Q, and held by the pin *u*′: the axis is round in the parts where it rests in the forks, and these are of such a weight that when the flat portion of the bar is turned down it only touches the tails of the upper jaw V, Fig. 849, of the pincers, without pressing them, and the pincers remain closed; but when this axis is turned a little round it presses on the tails of the pincers, and opens them by overcoming the elasticity of the springs *t*′. The axis U is turned round by means of two toothed sectors at the end, working in a vertical bar, also toothed and sliding against the branch Q.

The man can also open and shut the pincers by operating with his feet upon the pedals P. The axis P″ in the steel plate, set in motion by these pedals, carries at its extremity on the right a piece *p*″ which acts on the lever *n* O, which, being toothed on two-thirds of its circumference, performs the office of a pinion. This toothed portion engages a sector *r* on the extremity of an axis R, which turns upon itself, and is supported by projections *r*′ *r*′ fixed to the middle of the lower horizontal bars of the frame. A rack attached to this axis works into the upright, which is toothed at the lower end, and this upright acts upon the iron bar U as already explained.

The threads get stretched in proportion as the carriage is run out, but as this tension has no elastic play, too much force and consequent rupture is prevented by adapting to the carriage a mechanism, by means of which all the threads are pressed at the same time by a graduated weight. A little below

the prismatic bar which carries the pincers, is a shaft Y, carried by pieces *y* fixed to the arms Q, in which it can turn. At its left it carries two small bars, *y'* and *w'*, Fig. 849, and at its right a single bar *y'*, and a counterweight. The ends of the two bars *y'* are joined by a straight iron wire. When the carriage approaches the web, and before the iron wire can touch it, the small bar *w* presses against a pin *w'*,

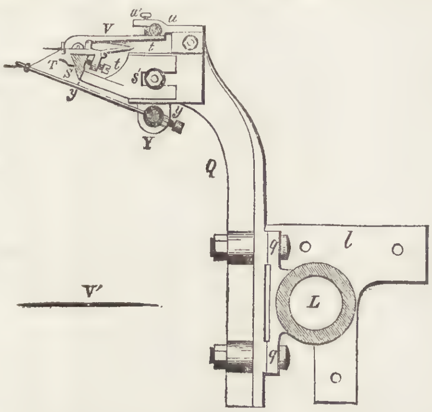


Fig. 849.

which rests upon it, and tends to raise it more and more; the bars *y' y'* and the iron wire are lifted up at the same time, and take the position shown in Fig. 850, but when the carriage, setting out from this position,

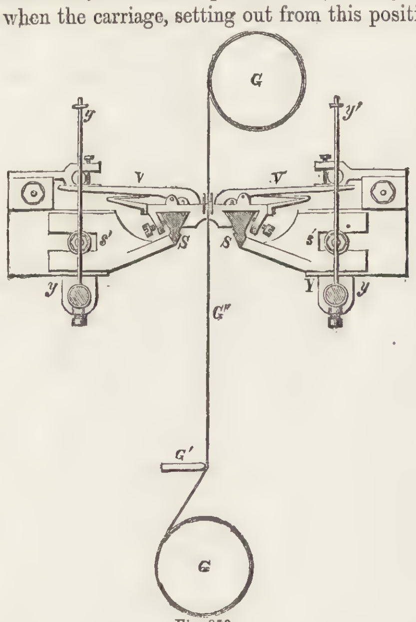


Fig. 850.

is withdrawn from the web, the bar *w* glides in, descending on the bar *w'*, and then escapes to a certain distance, and the counterpoise causes the bars *y'* to fall and depress the wire, so as to act on all the threads. The position is then the same as is shown in Fig. 849.

The Editor saw this machine in operation a few years ago at Mr. Houldsworth's silk mill at Manchester, and it is now used in several parts of the kingdom. The machine was attended by a young woman who managed the pantograph, and two children who regulated the motions of the carriages. A piece of black velvet was being embroidered with flowers. Much care is required in the management of the pantograph. The operative must not follow slidingly with the point of the style the trace of the design upon the tablet, but must rest the point of the style upon the point of the pattern into which the needle is to be inserted, then remove it, and put it down again upon the point by which the needle ought to re-enter in coming from the other side of the piece; and so on in succession. To assist these manipulations, the pattern in the tablet is composed of right lines terminated by the points for the entrance and return of the needle, so that the operative has continually under her eyes the series of broken lines which must be followed by the pantograph. If she quit this path for an instant, without having left a mark of the point at which she had arrived, she must look at the web to see what has been already embroidered, and thus ascertain the point at which she must resume her work, so as not to leave a vacant space, or repeat the same stitch.[1]

EMERALD. (Italian, *Smeraldo*, from the Greek, Σμαράσσειν, to shine, to be bright.) This precious stone, which ranks next to the diamond, and is equal to oriental ruby and sapphire, is of a beautiful green colour. It occurs in prisms, with a regular hexagonal base; sp. gr. 2.7; it scratches quartz with difficulty, and is scratched by topaz, and fuses before the blowpipe into a frothy bead. Its analysis has been differently stated by different chemists; but it appears to contain about 14 per cent. of glucina, (which is its characteristic constituent,) 68 of silica, 16 of alumina, and a very small portion of lime and iron: it also contains less than 1 per cent. of oxide of chromium, to which it owes its colour. The paler varieties of this stone are known under the name of BERYL: they are coloured by oxide of iron. *Aquamarine* includes clear beryls of a sea-green, or pale bluish, or bluish green tint.

The finest emeralds come from Grenada, where they occur in dolomite. A crystal from this locality, in the cabinet of the Duke of Devonshire, measures in its greatest diameter $2\frac{2}{8}$ths inches nearly; its lesser diameter barely 2 in.; its third diameter $2\frac{1}{8}$th in.: the extreme length of the prism is 2 inches. It contains several flaws, and is therefore only partially fit for jewellery; it has been valued at more than 500 guineas. A more splendid specimen, weighing 6 ounces, belonging to Mr. Hope, cost 500*l*. Both these specimens are exhibited in the Great Exhibition. Emeralds of less beauty, but of very large size, occur in Siberia. One specimen in the imperial collection of Russia measures $4\frac{1}{2}$ inches in length and 12 in breadth. Another is 7 inches long and 4 broad, and weighs 6 lbs.

The finest beryls (*aquamarines*) come from Siberia, Hindostan, and Brazil. In the United States very large beryls have been obtained, but seldom transparent crystals: they occur in granite or gneiss. A reputed beryl of large size mentioned in most books on mineralogy has recently been discovered to be a lump of quartz.

(1) The embroidering machine is described in the Bulletin de la Société Industrielle de Mulhausen, No. 38. Tome viii. 1835.

Euclase and *chrysoberyl* contain glucina as a characteristic, and belong to this group.

EMERY, a mixed granular corundum, extensively used in the arts for grinding and polishing metals, glass, &c. The use of emery in the arts is of very ancient date, as is proved by the existence of works on hard stones, which could not have been executed except by the use of emery, or of minerals of that nature. It is probable that some of the localities of emery which have recently been discovered were known to the ancient Greeks and Romans. Thus, the locality of Gumuch-dagh is near the ancient Magnesia, on the Meander, and between Ephesus and Tralles, twelve miles from each of these cities, and the same distance from Tyria, in all which cities the arts flourished, especially the art of cutting hard stones, if we may judge from the specimens which have been transmitted to modern times. The quantity used was, however, very small compared with what it now is, especially since plate-glass has become so common.

During several centuries, down to within the last two or three years, the island of Naxos, in the Grecian Archipelago, was the only source for the supply of emery. This kind is often known under the name of *Smyrna* emery, from the fact of its coming to us from that port. Its price at the end of the last century was from 7*l.* to 8*l.* 10*s.* per ton; and between the years 1820 and 1835, even less than this. About this period, the monopoly of the Naxos emery was purchased from the Greek government by an English merchant, who so regulated the quantity given to commerce, that the price gradually rose from 7*l.* to 30*l.* per ton, a price at which it was sold in 1846 and 1847. About this time, however, Dr. J. Lawrence Smith, an American mineralogist, being at Smyrna, saw some specimens of emery ore from a place twenty miles north of that port, which had been discovered through the agency of a knife-grinder of the country, who had been in the habit of using it to charge his wheels with. The importance of this circumstance to the Turkish government, as well as to the arts, induced Dr. Smith, in 1847, to examine the supposed locality of this mineral. An English merchant named Healy also pointed out other localities of the mineral. The first locality examined was that of Gumuch-dagh, a mountain about twelve miles east of the ruins of Ephesus, and composed of bluish marble resting on mica slate and gneiss. On the very summit of the mountain the emery was found scattered about, and projecting above the surface of the soil. In was in great profusion, in angular fragments of a dark colour, and in large masses of several tons' weight. On penetrating the soil, the emery was found imbedded in it, and a little further down it was come to in the rock. By breaking the marble that projects above the surface at this spot, nodules of the mineral were found. In some places the emery formed almost a solid mass, several yards in length and breadth, the spaces between the blocks being filled with an earth highly charged with oxide of iron. In other places the masses were consolidated by carbonate of lime of infiltration, which must not be confounded with the emery in its original gangue (the marble), in which it is found in nodules, sometimes round, and at other times fissured so as to represent angular fragments. In no place did it present anything like a vein, nor had it signs of stratification The largest unbroken mass seen by Dr. Smith must have weighed from 30 to 40 tons.

Other localities of emery are Kulah, Adula, and Mauser; also the island of Nicaria, in the Grecian Archipelago. In the island of Naxos the emery is found in large blocks mixed with a red soil, and also imbedded in white marble. It is taken principally from the north and east side of the island: the best comes from Vothric, nine miles from the shore, and is embarked at Sulionos. Another good locality is at Apperanthos, seven miles from the shore, and it is embarked at a small port called Montzona. In the south of the island it is found near Yasso. It is in such abundance on this island that, notwithstanding the immense quantity carried off, it has not yet been found necessary to quarry the rock.

Dr. Smith having reported his discoveries to the Turkish government, a commission of inquiry was instituted, and the business soon assumed a mercantile form. The monopoly of the emery of Turkey was sold to a mercantile house in Smyrna, and since then the price has diminished in the English market to from 10*l.* to 15*l.* the ton. The different mines explored are those of Naxos, of ancient date; of Kulah, commenced in 1847, and now abandoned for those nearer the sea; of Gumuch-dagh, commenced in 1847, and worked largely; and of Nicaria, commenced in 1850. From all these different places the emery is sent to Smyrna, and from thence principally to England, the vessels taking it at a very low price, as it serves for ballast. The various mines belong to the Turkish and to the Greek governments. The latter now sells its emery in lots of several tons; but as the former has sold the entire monopoly of its mines, the operations are controlled by a single interest: but it is expected that this monopoly will be abolished in virtue of a commercial treaty existing between Turkey and the other powers. The effect of this will be greatly to reduce the price of emery.

Of the different varieties of emery used in the arts, that of Naxos is still preferred, as it is more uniform in its quality than that from Kulah and Gumuch; but if the best qualities of Nicarian emery are found in abundance, and such only sent to the market, they will prove equal, if not superior, to the emery of Naxos.

The mining of emery is of the simplest character. The natural decomposition of the rock in which it occurs facilitates its extraction. The rock decomposes into an earth in which the emery is found imbedded. The quantity procured under these circumstances is so great that it is rarely necessary to explore the rock. The earth in the neighbourhood of the block is almost always of a red colour, and serves as an indication to those who are in search of the mineral. Sometimes, before beginning to excavate, the spots are sounded by an iron rod with a steel point, and when any resistance is met with, the rod is rubbed in

contact with the resisting body, and the effect produced on the point enables a practised eye to decide whether it has been done by emery or not. The blocks which are of a convenient size are transported in their natural state, but are frequently broken by large hammers: when they resist the action of the hammer, they are subjected to the action of fire for several hours, and on cooling they most commonly yield to blows. It sometimes happens that large masses are abandoned, from the impossibility of breaking them into pieces of a convenient size, as the transportation either on camels or horses requires that the pieces shall not exceed 100 lbs. each in weight.

At Kulah, the quantity of emery detached from the rock was not very considerable, as it had been protected from decomposition by the beds of lava that cover it. There the marble was quarried to get at the emery, which was done in 1847 with profit, although the emery had to be carried 110 miles on the backs of camels. Since the diminution of the price of emery, this mine has been abandoned, for the quarrying into the marble was found very difficult, the tools used in boring, &c. being thrown out of use in a very short time by the pieces of emery encountered at every instant. At the time when Dr. Smith wrote, all the emery sent from Asia Minor was from the mine at Gumuch-dagh.

Emery appears to be a mechanical mixture of corundum and oxide of iron: that from Naxos is of a dark grey colour, with a mottled surface, and with small points of a micaceous mineral disseminated in the mass. It frequently contains bluish specks or streaks, which are easily recognised as being pure corundum. The emery from the other localities has each its own peculiar aspect. The fracture of emery is tolerably regular, and the exposed surface granular: it is exceedingly difficult to break when not traversed by fissures, or not of a lamellated structure. When reduced to powder, it varies in colour from dark grey to black. The colour of its powder affords no indication of its commercial value. The powder examined under the microscope shows the distinct existence of the two minerals, corundum and oxide of iron. Emery when moistened always affords a very strong argillaceous odour. The specific gravity is about 4. Its hardness is its most important property in its application to the arts, and was ascertained by Dr. Smith in the following manner: Fragments are broken from the piece to be examined, and crushed in a diamond mortar with two or three blows of a hammer, then thrown into a sieve (with 400 holes to the square centimetre). The portion passing through is collected, and that remaining on the sieve again crushed, and so on until all the emery had passed through the sieve. The powder is then weighed, and the hardness tested with a circular piece of glass, about 4 inches in diameter, and a small agate mortar. The glass is first weighed, and placed on a piece of glazed paper: the pulverized emery is then thrown upon it at intervals, rubbing it against the glass with the bottom of the agate mortar. The emery is brushed off the glass from time to time with a feather, and when all the emery had been made to pass once over the glass, it was collected, and passed through the same operation three or four times. The glass was then weighed, again subjected to the same operation, the emery by this time being reduced to an impalpable powder. This series of operations is continued until the loss sustained by the glass is exceedingly small. The total loss in the glass is then noted, and when all the specimens of emery are submitted to this operation under the same circumstances, an exact idea of their relative hardness is obtained. The advantages of using glass and agate are, that the latter is sufficiently hard to crush the emery, and in a certain space of time to reduce it to such an impalpable state that it has no longer any sensible effect on the glass; and, on the other hand, the glass is soft enough to lose during this time sufficient of its substance to allow of accurate comparative results. By this method, the best emery was found capable of wearing away about half its weight of common French window-glass. The blue sapphire of Ceylon, pulverized and experimented with in this manner, wears away more than four-fifths of its weight. This furnished the standard of comparison.

The following Table shows the results of the examination of ten specimens of emery:—

No.	Localities.	Effective Hardness. Sapphire 100	Specific Gravity.	Chemical Composition.					
				Water.	Alumina.	Oxide of Iron.	Lime.	Silica.	Total.
1.	Kulah	57	4.28	1.90	63.50	33.25	0.92	1.61	101.18
2.	Samos	56	3.98	2.10	70.10	22.21	0.62	4.00	99.03
3.	Nicaria	56	3.75	2.53	71.06	20.32	1.40	4.12	99.43
4.	Kulah	53	4.02	2.36	63.00	30.12	0.50	2.36	98.34
5.	Gumuch	47	3.82	3.11	77.82	8.62	1.80	8.13	99.48
6.	Naxos	46	3.75	4.72	68.53	24.10	0.86	3.10	101.31
7.	Nicaria	46	3.74	3.10	75.12	13.06	0.72	6.88	98.88
8.	Naxos	44	3.87	5.47	69.46	19.08	2.81	2.41	99.23
9.	Gumuch	42	4.31	5.62	60.10	33.20	0.48	1.80	101.20
10.	Kulah	40	3.89	2.00	61.05	27.15	1.30	9.63	101.13

Other substances in very minute quantities occur in some of the emeries, as titanic acid, oxide of manganese, oxide of zirconium, and sulphur. Those emeries which contain the least water, everything else being alike, are the hardest. The silica is usually in combination with alumina, or the oxide of iron, or

both; so that the quantity of alumina must not always be regarded as an indication of the quantity of corundum in the emery.[1]

We come now to describe the various methods adopted in this country for preparing emery for the manufacturer and the mechanic.[2] In the ordinary process, the lumps of emery ore as they are imported are broken up in the same manner as stone is for repairing macadamized roads, and into lumps of similar size. These lumps are then crushed under stampers, such as are used for pounding metallic ores, driven by water or by steam power. It is supposed that the stampers leave the fragments more angular than they would be if ground under runners, a mode which is sometimes employed. The coarse powder is then sifted through sieves of wire-cloth, which are generally cylindrical, like the bolting-cylinders of corn-mills; but the sieves are covered with wire-cloth, having in general about 90 to 16 wires to the inch. The following figures show the numbers of wires usually contained in the sieves, and the names of the kinds respectively produced by them:—16. Corn emery; 24. Coarse grinding emery; 36. Grinding emery; 46. Fine grinding emery; 53. Super grinding emery; 60. Coarse flour emery; 70. Flour emery; 80. Fine flour emery; 90. Superfine flour emery. No. 16 sieve gives emery of about the size of mustard-seed; and coarser fragments, extending nearly to the size of peppercorns, are also occasionally prepared for the use of engineers. The sieves have sometimes as many as 120 wires in the inch; but the very fine sizes of emery are more commonly sifted through lawn sieves. The finest emery that is obtained from the manufacturers is that which floats in the atmosphere of the stamping-room, and is deposited on the beams and shelves, from which it is occasionally collected. The manufacturers rarely or never wash the emery: this is mostly done by the glass-workers, opticians, and such others as require a greater degree of precision than can be obtained by sifting.

Washing-over, or *elutriation*, as the process is called by chemists, is a beautiful application of the law of gravitation to the useful arts.[3] Thus the alluvial deposits of some of the tropical rivers are washed in order to separate the particles of gold which they contain. A small portion of the mud of the river is stirred in a large quantity of water contained in a broad shallow basin, the gold, being many times heavier than the earthy particles, quickly subsides, and the mud, which remains suspended for a long period in the water, is removed by pouring off the water from the valuable sediment. In a similar manner the particles of emery and other powders may be separated according to their magnitudes, in a more accurate manner than can be accomplished by sieves. A portion of emery-powder of uncertain size is thoroughly well mixed in a large quantity of water, as in a common wash-hand basin, and at the end of 10 seconds the liquid is poured off from the sediment which has fallen down in that period; the sediment is laid aside in a separate vessel. The bulk is again stirred and poured off at 10 seconds, and this second sediment added to the first, which process is repeated until no further sediment is deposited in the period of 10 seconds; the process requires watchfulness and a steady hand. A fresh deposit is similarly collected from the residue after a longer period of rest, say 20 seconds, until the whole quantity of emery is divided into grains of so many sizes, as may be required for the particular branch of manufacture for which it is intended. Mr. Holtzapffel states, that for many years he used emeries in the construction of mechanism of twelve degrees of fineness, part of them prepared by himself, by washing-over, namely:—No. 1. Corn emery of commerce; No. 2. Grinding emery; No. 3. Fine grinding emery; No. 4. Superfine grinding emery; all prepared by sifting: No. 5. Deposited at the end of two seconds; No. 6, at the end of five seconds; No. 7, ten seconds; No. 8, twenty seconds; No. 9, sixty seconds; No. 10, three minutes; No. 11, fifteen minutes; No. 12, sixty minutes. The emeries of the sizes 5 to 12 are preserved in glass bottles, to keep them pure.

In the preparation of emery for optical purposes, Mr. Ross mixes 4 pounds of the flour emery of commerce, with 1 ounce of powdered gum arabic, and then throws the powder into 2 gallons of clear water. He collects deposits, as above described, at the end of 10 seconds, 30 seconds, 2 minutes, 10, 20, and 60 minutes, and that which is not deposited by 1 hour's subsidence is thrown away as useless for grinding lenses. The use of the gum arabic, which renders the water slightly viscid, was recommended by Dr. Green for preparing red oxide of iron, for polishing specula.

Another mode of preparing emery was pointed out some years ago by Mr. Hawkins. That gentleman finding that the emery sold in the shops was inadequate to the purpose of grinding two flat surfaces of hard cast steel accurately, thought of applying to emery a process which he had seen for washing over diamond dust. To ensure a good hard quality of emery, he procured of an emery-maker a quantity of those small lumps or grains which had longest withstood the action of the cast-iron runners and bed: these pieces were reduced to powder in a cast-iron mortar and then separated into different portions by sieves. The finest emery thus obtained was washed over with oil instead of water, the oil holding it in suspension a much longer time, and in this way he obtained a series of emeries which had floated 1, 5, 10, 15, 20, 40, and 80 minutes, amongst which he found every variety necessary for his purpose, and keeping them in boxes which were numbered ac-

(1) "Memoir on Emery," by J. Lawrence Smith, M.D. Read before the Academy of Sciences of the French Institute, July 15, 1850, and communicated to the American Journal of Science and Arts by the Author.

(2) Our information on this subject is chiefly derived from Holtzapffel's "Mechanical Manipulation," vol. iii.; Nicholson's "Journal of Natural Philosophy;" and Gill's "Technological Repository."

(3) An example of this is given under the article Cobalt, in the manufacture of Smalt.

cording to the minutes they had floated, he could at any time prepare more of any one kind. In this way Mr. Hawkins readily attained his object, and by selecting those grains of emery which resisted longest the action of the pestle and mortar, he obtained some so hard as to be capable of cutting a ruby when employed instead of diamond dust.

Mr. Gill, by grinding Greek emery-stone between two flat and hard steel surfaces and washing off the lighter portions in oil, found that those which subsided in half a minute, when examined by a microscope, had entirely resisted the friction, and were perfectly crystallized sapphires.

Mr. Chezy prepared very fine emery for optical purposes in the following manner:—After having well ground the coarse emery on an iron plate with an iron muller, it is thrown into a vessel which must be rather wider at bottom than at top by a gradual increase. The vessel must then be filled with clear water, so that it may stand 8 or 10 inches above the emery. The whole is then strongly agitated with an iron spatula and left to settle for an hour. The short branch of a syphon is then introduced to the depth of 4 inches below the surface, and the turbid water withdrawn without disturbing the vessel. The water thus drawn off is received into another large vessel, and the first vessel is again filled and its contents agitated as before. The same operation is repeated until the water flows clear through the syphon. The powder collected in the second vessel is too fine for grinding glass. The vessel being emptied and cleared, the same operations are to be repeated, but the water is to be drawn off at the end of half an hour, until the water passes clear through the syphon. The emery thus obtained by subsidence, is preserved for use under the denomination of *emery of half-an-hour.* The same operation being repeated, allowing only a quarter of-an-hour for subsidence, gives a fine emery, but not so fine as the preceding; this is known as *emery of a quarter-of-an-hour.* In this way emeries may be obtained of $\frac{1}{2}$ or $\frac{1}{4}$ of a minute.

Washing emery by hand as above explained, is far too tedious for those who require very large quantities of emery, such as the manufacturers of plate-glass and some others, who generally adopt the following method:—Twelve or more cylinders of sheet copper, of the common height of about 2 feet, and varying from about 3, 5, 8, to 30 or 40 inches in diameter, are placed exactly level, and communicating at their upper edges, each to the next, by small troughs or channels; the largest vessel has also a waste-pipe near the top. At the commencement of the process, the cylinders are all filled to the brim with clean water; the pulverized emery is then churned up with abundance of water in another vessel, and allowed to run into the smallest or the 3-inch cylinder, through a tube opposite the gutter leading to the second cylinder. The water during its short passage across the 3-inch cylinder, deposits in that vessel such of the coarsest emery as will not bear suspension for that limited time; the particles next finer, are deposited in the second or the 5-inch cylinder, during the somewhat longer time the mixed stream takes in passing the brim of that vessel; and so on. Eventually the water forms a very languid eddy in the largest cylinder, and deposits therein the very fine particles that have remained in suspension until this period; and the water, lastly, escapes by the waste-pipe nearly or entirely free from emery. In this simple arrangement, *time* is also the measure of the particles respectively deposited in the twelve or more vessels, their number being determined by the quantity of sizes respectively required in the manufacture to which the emery is applied. When the vessels are to a certain degree filled with emery, the process is stopped, the vessels are emptied, the emery is carefully dried and laid by, and the process is recommenced.

Emery-paper is prepared by brushing the paper over with thin glue, and dusting the emery-powder over it from a sieve. There are about six degrees of coarseness. Sieves with 30 and 90 meshes per linear inch, are in general the coarsest and finest sizes employed. When used by artizans, the emery-paper is commonly wrapped around a file or a slip of wood, and applied just like a file, with or without oil, according to circumstances. The emery-paper cuts more smoothly with oil, but leaves the work dull.

Emery-cloth only differs from emery-paper in the use of thin cotton cloth instead of paper, as the material upon which the emery is fixed by means of glue. The emery-cloth when folded around a file, does not ply so readily to it as emery-paper, and is apt to unroll. Hence smiths, engineers, and others, prefer emery-paper and emery-sticks; but for household and other purposes, where the hand alone is used, the greater durability of the cloth is advantageous.[1]

Emery-sticks are rods of deal about 8 to 12 inches long, planed up square, or with one side rounded like a half-round file. Nails are driven into each end of the sticks as temporary handles, they are then brushed over one at a time with thin glue, and dabbed at all parts in a heap of emery-powder, and knocked on one end to shake off the excess. Two coats of glue and emery are generally used. The emery-sticks are much more economical than emery-paper wrapped on a file, which is liable to be torn.

Emery-cake consists of emery mixed with a little suet chopped small, rendered down, and mixed with a very little bees'-wax, so as to constitute a solid lump, with which to dress the edges of buff and glaze wheels. The ingredients should be thoroughly incorporated by stirring the mixture whilst fluid, after which it is frequently poured into water, and thoroughly kneaded with the hands, and rolled into lumps before it has time to cool. The emery-cake is sometimes applied to the wheels whilst they are revolving; but the more usual course is, to stop the wheel, and rub in the emery-cake by hand. It is afterwards smoothed down by the thumb.

Emery-paper, or *Edwards' patent razor-strop paper*, (patented in 1843,) is a new article, in which fine emery and glass are mixed with paper pulp, and made

(1) Edwards' patent for emery-cloth was taken out in December 1830.

into sheets as in making ordinary paper. The emery and glass are said to constitute together 60 per cent. of the weight of the paper, which resembles drawing-paper, except that it has a delicate fawn colour. This emery-paper is directed to be pasted or glued upon a piece of wood, and when rubbed with a little oil, to be used as a razor-strop.

Barclay's artificial emery-stone. In 1842, Mr. Henry Barclay took out a patent for a method of combining powdered emery into disks and laps of different kinds, suitable to grinding, cutting, and polishing glass, enamels, metals, and other hard substances. The process of manufacture is as follows: —Coarse emery-powder is mixed with about half its weight of pulverized Stourbridge loam and a little water or other liquid, to make a thick paste; this is pressed into a metallic mould by means of a screw-press, and after having been thoroughly dried, is baked or burned in a muffle or close receiver at a temperature considerably above a red heat, and below the full white heat. In this case, the clay or alumina serves as a bond, and unites the particles very completely into a solid *artificial emery-stone,* which cuts very greedily, and yet seems hardly to suffer perceptible wear.

Superfine grinding emery is formed into wheels exactly in the same manner as the above, but the proportion of loam is then only one-fourth instead of one-half that of the emery. These emery-stones, which are of medium fineness, cut less quickly, but more smoothly than the above.

Flour-emery when manufactured into artificial stones, requires no uniting substance, but the moistened powder is forced into the metal mould and fired; some portions of the alumina being sufficient to unite the whole. These fine wheels render the works submitted to them exceedingly smooth, but they do not produce a high polish on account of the comparative coarseness of the flour-emery. Stourbridge loam is not the only ingredient used in uniting the particles of emery. Many other substances answer as well; such as slate, Yorkshire gritstone, crocus, &c.; and in this way the hardness and cut of the emery-stone may be varied to a great extent. Most of the grinders made of the emery-stone are formed with central holes, so as to admit of being attached to the lathe upon appropriate chucks or spindles; and the substance is so porous as to absorb much water, which is gradually thrown to the surface by the centrifugal motion, so as to keep the edge conveniently moist, or with excessive velocity the water is thrown off as in trundling a mop. Mr. Barclay has made the disks of various diameters, from $\frac{1}{4}$ inch to 8 or 10 inches diameter, but the difficulty increases with the size, as the large ones are liable to warp and crack in the firing. When the emery-stone laps are required to have plane surfaces, angular or convex edges, &c., that could not be readily moulded, the composition is partially fired at a low heat, then turned in a lathe to the proper form, and fired at nearly a white heat. The coarse emery-stone has been used, it is said, successfully, in glass-cutting.

Common Corundum is much used in the East as an abrasive. Like emery, it owes its valuable property to the highly crystalline alumina of which it mostly consists. The lapidaries in India use corundum-wheels by cementing powdered corundum with one-third by volume of lac-resin. The corundum-powder is put into an earthen vessel and heated over a clear fire, and when hot enough to fuse a piece of resin easily, the resin is stirred in, in small portions at a time. The mass is then taken out and beaten with a pestle upon a smooth stone, then rolled upon a stick, re-heated several times, and continually kneaded until a uniform mixture is produced. It is then separated from the stick, laid again upon a stone slab previously covered with very fine corundum-powder, and flattened into the form of a wheel by an iron rolling-pin. The wheel is then polished by a plate of iron and corundum-powder, and lastly a hole is made through the middle by a heated copper or iron rod. These wheels are made with a grain more or less fine. The coarser perform the first rough work, and the finer cut the stones, which are moistened and sprinkled with corundum-powder. These wheels are mounted on a horizontal axis, and the workman sitting on the ground, makes them revolve with a spring bow held in his right hand, while the stone to be cut is held in his left. The polish is given by wheels of lead and very fine corundum-powder.

Corundum-rubbers are made by melting lac, and then intimately mixing corundum-powder with it. The composition is then moulded in the shape of a brick of about 6 by 4 inches, and $1\frac{1}{2}$ inch deep, with a handle of wood about 6 inches long at the end, having a rise of about 30° for the convenience of working it. For coarse rubbers the proportions are, by weight, lac 8, corundum 1; for the medium, lac 12 to 16, and corundum 1. The fine rubber is made by mixing the grindings of agates, carnelians, and the like with lac, and as the wheels upon which they are ground are made of corundum and lac, the grindings must contain a portion of those materials. A good proportion is 6 lac to 1 grindings.

Mr. Holtzapffel states that some dentists employ old files thinly coated with a cement of emery and shell lac in finishing enamel or mineral teeth.

ENAMEL AND ENAMELLING. An enamel is a vitreous substance used for painting on glass, porcelain, &c., and for covering metals with various kinds of useful and ornamental work. When the painting is complete, or the metal is covered, adhesion is produced by exposing the article to a temperature sufficiently high to fuse the enamel. Hence there are several conditions which enamels are required to fulfil: they must be fusible at a certain moderate temperature; they must adhere strongly to the glass, porcelain, or metal to which they are applied; they must have a certain transparency or opacity, such as will enable the artist to produce the effects of a finished picture; they must preserve a smooth vitreous appearance after fusion, and be sufficiently hard to resist the friction of solid substances; they must be insoluble in water and also resist the action of the atmosphere; and

lastly, they must contract and expand to the same extent as the substances which they cover.

In the present article we shall confine our attention chiefly to the enamelling of metals, referring to the article Pottery and Porcelain for some details respecting *enamel-painting*.

Enamels are composed of colouring-matters, which for the most part consist of metallic oxides, and, secondly, of fluxes, or vehicles for the colour, consisting of vitrifiable substances, such as silicates, borates, or boro-silicates, in different proportions. The colour of an enamel results either from the colour of one of its constituents, or is a result of the chemical combination of the constituents: in the one case, the colouring-matter is simply mixed with the flux, or, if the flux combine with it chemically, it does not affect its colouring property; in the other case, the flux has a chemical action on the colouring-matter.

Gold, silver, and copper are the metals which are usually enamelled. The enamels used for the purpose must have their point of fusion below that of the metals to which they are applied; it must be higher for copper and silver than for gold. They must be very fusible when used alone; but when they form a ground for other enamels, they must be capable of resisting a high temperature without fusing.

Enamels are opaque or transparent: those which are used as a ground are opaque; those which are used in painting may be transparent or opaque, but the latter are usually preferred, especially for silver and copper.

Enamelling on metals is more difficult than on glass and porcelain. The presence of an oxidizable metal usually produces a reaction between the two bodies: the enamel dissolves the oxide which forms on the surface of the metal at a high temperature, and becomes coloured thereby; or the enamel may itself oxidize the metal, in consequence of the oxide of lead contained in it, in which case the lead is reduced, and the colour is destroyed. Hence gold admits of being enamelled better than copper and silver; but if gold contain copper, some difficulties may be experienced. On copper and silver the enamel generally undergoes some change, at least in the layer which is in contact with the metal. If the enamel is transparent, the defects are apparent; but if opaque, and the surface smooth, the defects are concealed. Copper and silver are sometimes first covered with an opaque enamel, and afterwards with one that is transparent.

The objects to be enamelled are usually prepared for the purpose by the jeweller. They may be entirely or only partially covered with enamel, according to the design. In the one case there must be a projecting edge to retain the enamel, and in the other, certain hollows engraved according to the design.

All the enamels which are applied to metals have a vitreous, transparent, colourless base. The following are recipes for transparent enamels:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Silica......	3 parts	3 parts	3 parts	10 parts	3 parts
Minium...	3 —	4 —	5 —	15 —	6 —
Nitre......	2·5 —	2 —	1 —	4 —	0 —
Borax.....	0 —	1 —	1 —	1 —	1 —

Opacity is given to enamels by the addition of a certain proportion of—1, oxide of tin, 2, phosphate of lime, or 3, oxide of antimony. The oxide of tin is first combined with the oxide of lead before the enamel is made. For this purpose, metallic lead and tin are fused together, and raised nearly to a red heat: the oxide which forms on the surface is removed as fast as it is formed; heat is again applied, to render the oxidation more complete. It is next stirred up in water to precipitate the minute portions of metal which have escaped oxidation, and in this way the oxide can be separated.

The proportions of tin and lead which are to be thus fused together vary according to the composition of the enamel into which these oxides enter. A quantity of oxide of tin equal to about one-tenth of the weight of the enamel will render it of an opaque white. The proportion of lead is variable according to the kind of enamel required. For this purpose the following alloys will be found useful:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Lead......	3.5 parts	5 parts	6 parts	6 parts	7 parts
Tin	1 —	1 —	1 —	1 —	1 —

In the following recipes for opaque enamels, the oxide of one or other of these alloys is used instead of the oxide of lead in the transparent enamels:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Silica	3 prts.	3 pts.	3 pts.	10 pts.	3 pts.
Alloy	(No. 1) 4 —	(No. 2) 5 —	(No. 3) 6 —	(No. 4) 18 —	(No. 5) 7 —
Nitre	2.5	2 —	1 —	4 —	0 —
Borax.........	0 —	1 —	1 —	1 —	1 —

The above enamels are those adapted to gold. The more fusible enamels required for copper and silver may be formed by the addition of one-eighth of their weight of calcined borax. By the further addition of this substance the fusibility of enamels may be increased at pleasure.

Coloured enamels may be formed either opaque or transparent, by melting up with any one of the above enamels a certain proportion of some metallic oxide, as indicated in the following recipes:—

		Parts.
Blue enamel.	—Take opaque or transparent enamel	10
	Oxide of cobalt	1 to 2
Green enamel.	—Opaque or transparent enamel ...	6
	Oxide of chromium	1 to 2
Another green.	—Opaque or transparent enamel ...	30
	Binoxide of copper	1 to 2
Violet enamel.	—Opaque or transparent enamel ...	30
	Peroxide of manganese	1 to 2
Yellow enamel.	—Opaque or transparent enamel ...	6
	Chloride of silver	1 to 2
Purple enamel.	—Opaque or transparent enamel ...	12
	Purple of Cassius	1 to 2
Black enamel.	—Transparent enamel.	15
	Oxide of copper, oxide of cobalt, and oxide of manganese, 1 to 2 parts of each.	

Recipes for enamels used in painting on porcelain will be given in the article Pottery and Porcelain.

The enamels which are applied to metals are ground up with water in an agate mortar, and kept ready for use under water in a covered vessel. The metals to be enamelled must be made perfectly clean by being boiled in a solution of potash, and then washed in pure water. If gold be alloyed, it ought to be boiled

in a very strong solution of 40 parts saltpetre, 25 alum, and 35 sea-salt. This will remove the copper from the surface, and enable the enamel to make contact with pure gold.

A tolerably complete idea may be formed of the art of enamelling by the following detail of the processes concerned in the manufacture of watch-dial plates, which are manufactured in considerable numbers in this country. Enamelled dial-plates are of two kinds: the *hard*, in which the surface is covered with hard or Venetian enamel, and the *soft*, in which English soft glass enamel is used. The metals best adapted for the basis of the plate are fine gold or fine copper: the latter is most common, and is known by the name of *enamellers' copper*. The copper must be very thin, or the plates will crack in firing. The copper, having been cut into squares of the proper size, is heated to redness in a clear fire: when cold, the squares are formed into the intended shape of the dial. The tools required by the enameller are as follows: 1. The *dies*, one of which is shown in section in Fig. 851: these are small circular plates of brass,

Fig. 851.

about $\frac{1}{20}$th inch thick: their edges are turned a little conical, and their centres perforated with holes nearly as large as those to be made in the dial-plates. The enameller has about forty of these, from $\frac{3}{4}$ inch to $2\frac{1}{4}$ inches in diameter. 2. A round-ended punch, Fig. 852, made of steel wire about $\frac{3}{16}$ths inch thick and $1\frac{1}{2}$ long, fixed in a convenient handle: it is

Fig. 852.

used for the purpose of punching up the copper in the centre-holes of the dies. 3. A clock-maker's round broach, Fig. 853, firmly fixed in a strong handle: its

Fig. 853.

use is to burnish up an edge to the copper, and also to square up the centre-holes. 4. A die or block, Fig. 854, to set the copper of the desired concavity: this is of box or other hard wood, and a little larger in diameter than

Fig. 854.

the largest brass die: it has a hole through the centre something wider than the hole in the dial-plate. 5. A large pair of scissors, for cutting the copper into shape. 6. A setting spatula, Fig. 855, made of steel wire about $\frac{3}{16}$ths inch in diameter and 5 inches long,

Fig. 855.

with one end beaten flat and thin, then filed a little round, and the flat part bent so as to form a segment of a circle somewhat smaller than the curve of the setting-die: the outer part of the curve should then be smoothed on an oil-stone. 7. A smooth needle-makers' file, used for filing the plated wire and the edge of the copper after it has been burnished up to the edge of the brass die. 8. A small steel point, rather stouter than a stocking-needle, used for marking the place where the feet of the dial should be put. 9. A large soldering-lamp, Fig. 856, of the capacity of at least a quart: it has a cylindrical spout for the cotton at least $1\frac{1}{4}$ inch in diameter. 10. A pair of tweezers. 11. A blow-pipe for soldering the feet upon the coppers: the hole must be a little more open than is usual in blowpipes. 12. A watchmaker's glass and dial-gauge. 13. A pair of nippers, to cut the feet from the plated wire.

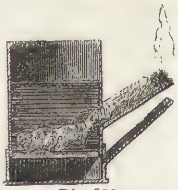


Fig. 856.

Supposing the workman finds, on measuring the frames of the watches which are to be furnished with dial-plates, that the frame corresponds with one of the divisions on the gauge, he selects a die half a size larger, as the dial must always be one size larger than the frame, including the thickness of the copper. The dial, when completed, ought to extend over the frame just enough to fill the groove in the inner case of a watch, turned for that purpose. If the dial is to be made to a brass edge, the die should be fully one size less than the inner rim; for as the dial has to lie within the rim of the edge, an allowance must be made for the thickness of the copper, and also for the swelling of the plate in the fire. The proper die being chosen, one of the pieces of copper must be placed on that side of the die which has the smallest diameter, and as nearly in the centre as possible; the die with the copper upon it is then placed flat on a table or board, and the round-headed punch, Fig. 852, being put in the centre, it is pressed down and worked round till the end of it is forced as far as it can go into the centre hole of the die. The copper is then taken off, and the bulge thus formed filed nearly through. The copper is then placed on the die in the same manner as before, and the round broach gently thrust through the centre hole till it fits it nearly tight to the die. Then holding the die and copper in the left hand with the die upwards, the copper is cut as nearly round as possible, leaving it about $\frac{1}{30}$th inch larger than the smallest side of the die, which is done by holding the scissors a little aslant. The die, with the copper uppermost, is then to be laid on the work-board, and gently rubbed or burnished over with the round broach, till the copper lies quite smooth and flat on the die. Then holding the die and the copper firmly in the left hand, and having the broach in the right, that part of the copper is to be burnished which extends beyond the edge of the die; this is best done by rubbing the broach round the copper and pressing it close to the edge of the die. The copper is now to be taken off the die, and the edge or rim thus formed is finished by filing it till it is equal on every side. The centre hole must be filed a little to take off the ragged parts, but it must not be made so low as the edge, and the bur that is formed by filing must be scraped off with the edge of a graver. The copper is then set up to the desired convexity by placing it in the setting die, and rubbing it with the setting spatula till the copper touches in all parts. After this, the feet are soldered on; for which purpose, copper

wire plated with silver is very preferable to plain copper wire soldered with spelter. When the copper is set up properly, it is placed on the frame of the watch, then holding the copper and the frame in the left hand, the holes in the frame where the feet are to be placed are marked with the point or needle. The copper is then placed in the setting die, and small squares are described about each of the marks that have been made with the point, large enough to admit the foot wire to be placed within, the object of the squares being to throw up a bur or ridge to prevent the foot from slipping out of its place during the operation of soldering. The feet for the coppers are cut by fixing an iron peg into the work-board, and the pieces of plated wire being held against it, it will form a very good resistance to the action of the file. If coppers are to be made for flat plates, the feet should be filed at right angles; but if the plates are convex, they should be filed at an angle, as nearly as possible corresponding with the curve formed in the hollow part of the copper, because when the foot is placed on the copper it will be found to stand perpendicular to the base line or edge of the copper. The feet thus filed are cut off with the nippers; if for frame plates, about $\frac{3}{16}$ths inch long; but if for flat plates, about $\frac{1}{8}$th will be sufficient. A small quantity of borax is next rubbed upon a piece of slate with the addition of a few drops of water, into which the filed parts of the feet being slightly dipped will greatly assist the soldering. The copper is then held in the left hand, and the feet, taken up with the tweezers, are set in their proper places on the copper preparatory to soldering, which is done by placing the copper on a piece of charcoal and directing the flame of the lamp by means of the blow-pipe upon it, until the copper is nearly at a white heat; the silver solder then runs down to the copper and completes the soldering. If the feet have kept in their places, they will fit into the holes of the frames, but if they have shifted a little, the copper must be placed in the setting die with the feet upwards, and the frame being held over the feet, they must be bent into the proper direction, by introducing the setting spatula between the frame and the copper, until they fit into the holes of the frame. The copper is then to be gently withdrawn from the frame, and if any dents or bulges have been made, they must be removed by putting the copper into the setting die, and rubbing the spatula round the feet till such imperfections are removed. Lastly, the copper is cleansed in a dilute solution of nitric acid, then washed in clean water with a soft brush and a little white sand. If the scale is completely removed, they need not be again pickled in the acid.

The tools used in enamelling are, 1. An agate pestle and mortar to grind the enamel. 2. A small riveting hammer. 3. A flat spatula, $\frac{7}{8}$ths inch broad and a little thicker than those used for paint knives. 4. A spatula rather thicker than the last, but of equal breadth; one side of this is flat and the other a little curved. It must be of good steel, and is used to spread the hard enamel on the copper. 5. A spatula, Fig. 857, for spreading the hard enamel on the under

Fig. 857.

side of the copper; this is called the bottom spatula; it is similar to the setting spatula, but broader at the end. 6. A quill cut like a tooth-pick, for clearing the enamel out of the centre holes. 7. Two damask napkins for drying the water from the enamels. 8. A small basin with a cover to hold the enamel used for the tops of the dial-plates. 9. A gallipot to hold the enamel that is used for the bottoms. 10. A cylindrical block of wood to fix the copper on when it is ready to have the enamel laid on the top. This for common sized plates may be about $1\frac{1}{2}$ inch diameter and 6 inches long. Soft wax is fixed at one end of this, so as to form a kind of cap to the block. 11. A box or tray to hold the plates when the enamel is spread on them. It may be about 16 inches long, 9 broad, and $1\frac{1}{2}$ deep. 12. A small steel-faced anvil to hold in the hand to break the enamel on. The face may be about 1 inch in diameter.

The soft glass enamel, which is bought by the enameller, in cakes, is prepared by him for use in the following manner:—It is first broken up with the riveting face of the hammer, any parts coloured with black and red streaks being rejected, as they would contaminate the whole of the enamel. When it is broken up into fragments, not larger than small peas, it is carefully ground with water in the agate mortar, and the fine powder into which it is gradually reduced, is washed away four or five times during the grinding, by filling the mortar with clean water, and agitating the enamel with the broad flat spatula, stirring it up from the bottom, till the water appears quite milky: the enamel should then be allowed to settle to the bottom, and the water poured off. Great care must be taken to keep off specks of dirt, as these will form specks on the surface of the dial-plates. The grinding must be continued, until the enamel is reduced to the fineness of fine grain gunpowder; although, for some purposes, it need not be finer than maw-seed. When completely ground, and the flour washed away, the enamel is kept under water in the covered basin, until ready for use.

The Venetian hard enamel that is used for bottoms, is broken up with the hammer, and then crushed in a cylindrical iron mortar, with a pestle fitting into it. Having been pounded until it is as fine as the glass enamel, it is ground in the agate mortar, to an almost impalpable powder. This enamel is not to be washed, as the flour is in this case of use. When the enamel is ground, it is kept under water ready for use, for if allowed to get dry after being ground, it must be worked up again in the agate mortar, otherwise it is likely to blister in the fire.

The Venetian hard enamel, such as is to be used for the faces or tops of dial-plates, is selected with care, so that the colour may be pure. It is then placed on a piece of platinum in an enameller's muffle, and heated to redness; it is to be suddenly quenched

in very clean spring water, which will cause it to split up into very small pieces, which are ground in the agate mortar. The enamel is broken up in this way, to avoid using the hammer and steel pestle, because, if a small particle of steel gets into the enamel, it will do mischief. The flour separated during the washings is allowed to subside, and is added to the gallipot with that which is used for bottoms. When the enamel is ground sufficiently fine, it is kept in a wide-mouthed glass bottle with a glass stopple, and covered with strong nitrous acid.

All these preparatory steps being taken, we now proceed to show, first, the method of enamelling with soft glass enamel. A napkin is laid on the work-board, four times doubled: the copper is to be held in the left hand with the feet upwards, and a small quantity of the hard enamel for bottoms is taken out of the gallipot on the end of the bottom spatula, and spread roughly on the copper, covering it closely up to the feet and centre holes. It is then laid between the folds of the cloth, till a little of the water is absorbed, when it must be smoothly spread, with the convex side of the spatula. If too much of the water be not removed, the enamel can be easily spread from the parts where it lies thickest to those that are too thin, until a general evenness is produced. It must then be smoothly spread by drying it more with the napkin, and spreading it again with the spatula, pressing more lightly as the enamel gets dry. The centre hole must be cleared out by twisting the quill in it, and the operation of laying the bottom is then completed.

A clean napkin is next folded and placed on the board, so as to hang over the edge about three or four inches, a weight being put on it, to prevent its being dragged down. When the wax upon the laying-block has been softened and made of a shape fit to receive the copper, the latter must be placed evenly on, and the feet pressed into the wax, till the under enamelled surface of the copper nearly touches it. Or this is better done by placing the setting block on the copper and pressing it down, for in this way the shape of the copper is preserved, and the upper side secured from the perspiration of the hands, which might cause the enamel to blister. The copper is next brushed clean with a soft hair brush, or a hare's foot, taking care not to leave any of the hard enamel on the surface, or about the edge. The block with the copper on it is now to be held in the left hand, and a small quantity of the glass enamel is to be taken upon the end of a flat spatula, and laid upon the copper near the centre hole, taking care not to let the water pass through the centre hole, as that would take the enamel from the bottom, which could not be replaced without injuring the enamel on the top, and so the two kinds would get mixed, and both be spoiled. When a sufficient quantity of the glass enamel has been put upon the copper, it must be roughly spread, by repeatedly indenting the edge of the flat spatula into the enamel, crossing it in all directions till it lies of a uniform thickness all over the copper. The inequalities thus formed on the surface may be reduced by just tapping the side of the block two or three times with the edge of the spatula. The water which this operation will cause to flow on the surface of the enamel, must be dried a little with the corner of the cloth, but not so much as to render the enamel difficult to be moved. The side, or part of the enamel which is too thick, must be reduced, by removing a portion of it to places that appear deficient. This is done by spreading the spatula over the enamel, turning the block round with the fingers and thumb of the left hand, till it lies generally even. It is then dried again with the napkin, and the surface made smoother by passing the spatula over it in all directions, bearing a little harder on the enamel as it gets drier. As this rubbing and spreading of the enamel will attract the moisture to the surface, and prevent the enamel from lying smoothly, it must be dried again and laid by, passing the spatula lightly over the surface. In determining the thickness of the enamel, allowance must be made for its more bulky, granulated state, previous to melting. In enamelling the tops of convex plates, the *shoulder*, which is about one quarter of the distance from the edge to the centre, should be laid somewhat thicker than towards the edge, because the edge being lower than the centre, the enamel, when in a fluid state in the fire, will flow down to it, and thus produce an equality of thickness on all parts of the copper. When the copper is covered, it must be carefully removed from the block, by gently raising it with the back of the thumb-nail, under the edge, and as near each of the feet as possible. It is then to be placed in the covered tray and kept from dust, till wanted for firing.

In hard enamelling, the copper, made chemically clean, is fixed on the laying block as before, and a coat of soft enamel first laid on, about two thirds of the thickness of that used in soft enamelling. This must be fired till the enamel is melted down to a tolerably smooth surface, and when cold, should any specks of dirt appear, they must be cut out with the point of a square graver whetted to a very obtuse angle. The plate must then be put for a short time into a solution of nitrous acid, just strong enough to cleanse the scale from the edge of the copper: it must then be washed in clean water. The plate is next fixed on the laying block, the wax being made soft enough to admit the feet without any great pressure. A small quantity of hard enamel, thoroughly purified of the acid by washing in several waters, must next be spread equally over the whole surface of the plate, and the corner of a clean napkin laid upon it to absorb a portion of the water. The enamel can then be spread more equally over the surface of the plate: when nearly smooth and of equal thickness, it must be dried again and the spreading be continued for ten minutes, rubbing it evenly in every direction till it is compressed as closely as possible.

The next process is *firing*, by which the enamel is melted into a uniform mass on the surface of the copper. The apparatus used is a ring for supporting the edge of the dial while in the fire, so that the feet may not come in contact with any substance, or they

would be loosened. These rings are made of 1 part pipeclay and 2 parts black-lead. To prevent the adhesion of the enamel to the ring, one part of the ring is made like the frustrum of a very obtuse-angled hollow cone, while the other side forms a plane perpendicular to the sides of the cylindrical parts. The dial being laid in the hollow side will just touch it at the part where the copper is bare, and thus prevent the adhesion of the enamel, especially if this part of the ring be first rubbed with fine whitening. When the dial is placed on the ring, both are set on a flat circular stone or a slab of Stourbridge clay, and as the dial must be kept turning in the fire during the whole time of melting in order to be equally heated, the slab with the ring and dial upon it are set upon a small piece of clay moulded into the segment of a sphere 5 inches in diameter. The enamellers call this arrangement a *turner:* it is shown in section, Fig. 858,

Fig. 858.

in which A is a curved dial for a watch without a brass edge; B the ring; C the slab or *planch,* and D the turner.

The furnace being sufficiently heated, the enamelled plates must be laid upon the hearth on a ring of proper size, and they are left until the moisture is entirely evaporated. The planch having been raised to nearly a white heat in the fire, is withdrawn, and the plate and ring set on it as nearly as possible in the centre: when the whole is to be placed on the turner under the muffle and kept in motion until it assumes one uniform surface. It must then be withdrawn with the tongs, and another treated in the same way, till the whole day's work is fired: this may vary from three to six dozen plates.

It seldom happens that a plate will come out of the fire free from small black or green specks. The union of so many small particles will also produce an unpleasing mottled appearance. The specks must be removed by a square graver. The centre hole of the copper and also the edge will appear to rise above the surface of the enamel: these are to be carefully filed down, and the plate is then ready for *using off, i. e.* rubbing the surface on a gritstone with fine sand and water until the glazed appearance is removed, and a uniform rough surface is produced. This removes the mottled appearance and gives a more equal convexity to the plate. It also removes the semi-transparent appearance of the enamel, and greatly increases its intense whiteness, and beautiful opacity. After the using off, the plates are brushed with a stiff hair brush and wet sand, then washed in clean water, and dried. They are now ready for the finishing fire.

The holes left in picking out the specks are filled up with the finest enamel, almost as fine as flour, and the plate being placed in a proper sized ring, is set on the iron hearth of the furnace, gradually bringing it nearer to the fire until it attains such a heat as will permit it to be placed in the hottest part without danger of cracking. The ring and plate are then lifted upon the planch with the tongs, and kept in motion until a white heat is attained. This being done, it must be taken out of the fire and blown upon with the breath for a few seconds and immediately returned to the heat: this will bring out a beautiful gloss and a degree of whiteness not attained by other means. The proper effect being produced, the plate must be withdrawn and set to cool gradually. If free from specks, the plate is ready for the next process: if specks exist, they can only be removed with the graver, (omitting the using-off,) and the firing must be repeated.

In firing hard enamel dials, the heat must not be so great, and the plate must be taken from the fire as soon as the enamel is found to form a tolerably compact body.

The hours, &c. are painted on the dial in a soft black enamel prepared for the purpose. It is ground very fine in an agate mortar, and mixed with oil of spike-lavender until sufficiently diluted. A mark is made with a file on the edge of the dial, to indicate the place of number XII. Then, with the assistance of a division plate and its index, the divisions are slightly traced from the centre with a black lead pencil. The circular lines which contain the divisions of the hours, minutes, &c. are previously traced with compasses, one point of which is furnished with a cone, and the other with a port-crayon and pencil. When the painting is perfectly dry, the dial is once more fired.

The foregoing details contain most of the processes of the enameller. In ornamental enamelling, when the enamel is not intended to cover the whole surface of the plate, it is necessary to form a lodgment for it. The outlines of the design are therefore first drawn upon the plate with a black-lead pencil, and then traced with a graver. The spaces enclosed within the outlines of the design must then be deepened by proper tools, equal to the height which would have been given by the ridge or border had the plate been intended to have been enamelled all over. This deepening is effected with a flat graver; and it must be everywhere of equal depth, for if any raised portions be left, the enamel falls away, or is so thin in those parts as to show the metal through. The bottom of the lodgments for the enamel must be slightly hatched or roughened with the end of a small riffler file, broken square across, for the purpose of affording a hold to the enamel. The plate is then thoroughly cleaned, and is next covered with a coat

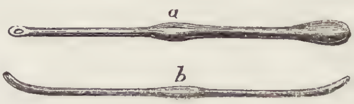


Fig. 859.

of white enamel laid upon it wetted with water,

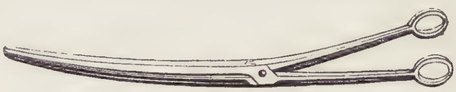


Fig. 860.

much skill being required to bring the enamel into

contact with the ridges or borders of the design. The spatula used in spreading the enamel is shown in two positions *a* and *b*, Fig. 859. A form of tongs used by enamellers is shown in Fig. 860.

In some cases the design is produced by stamping a steel die upon a gold strip, and the hollows thereby produced are filled up with differently coloured enamels by means of a steel point. This method calls for the display of much skill and taste on the part of the enameller. The enamels are mixed with water or with oil of lavender, according to circumstances; several layers are usually applied, the object being fired between the application of every two layers.

Previous to firing, the plate is laid upon a piece of sheet iron, Fig. 861, pierced with small holes, and put upon hot ashes to expel the moisture and to raise it to the proper temperature for introducing it into the muffle; for if inserted cold, it would cause the enamel to fly off.

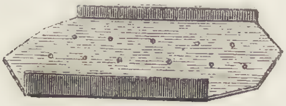


Fig. 861.

The enamelling of cast-iron vessels and other hollow ware for saucepans, &c., is an art which was introduced in the year 1799, and again in 1839. In the latter case, large sums of money have been expended in perfecting the processes, taking out patents and contesting the patent right. In the former year, Dr. Hickling obtained a patent for a process for lining iron vessels, &c. by fusion with a vitrifiable mixture, of which there were four kinds :—

The *first* was composed of 6 parts calcined flints, 2 parts of *composition* or Cornish stone, 9 parts of litharge, 6 parts of borax, 1 part of argillaceous earth, 1 part of nitre, 6 parts of calx of tin, and 1 part of purified potash.

The *second* consisted of 8 parts of calcined flints, 8 red lead, 6 borax, 5 calx of tin, and 1 of nitre.

The *third*, 12 of potter's composition, 8 borax, 10 white lead, 2 nitre, 1 white marble calcined, 1 argillaceous earth, 2 purified potash, and 5 calx of tin.

The *fourth*, 4 of calcined flint, 1 potter's composition, 2 nitre, 8 borax, 1 white marble calcined, $\frac{1}{2}$ argillaceous earth, and 2 calx of tin.

Each composition to be finely powdered, mixed, and fused: when cold, the resulting vitreous mass is to be ground, sifted, and levigated with water. It is next mixed up with water or gum-water, and brushed over the interior of the vessel to be coated, and then fused in a muffle.

The fusibility of the coating is to vary according to the heat which is to be applied to the vessel when in use. For this purpose the proportions of the siliceous and fluxing materials were varied. The use of lead in this process is very dangerous, and ought on no account to be allowed.

In May 1839, Messrs. Clarke obtained a patent for coating iron saucepans, in such a way as to prevent the enamel from cracking or splitting from the effects of fire. The vessel is first cleaned with dilute sulphuric acid, then boiled in pure water. The composition is next applied. This consists of 100lbs. of calcined ground flints and 50lbs. of borax calcined and finely ground: the mixture to be fused and gradually cooled. 40lbs. of this mixture is then ground with water with 5lbs. of potter's clay, into a pasty mass, such as will form a coat on the inner surface of a vessel about $\frac{1}{6}$ inch thick. This coating is *set* by putting the vessel in a warm room. The second coating or glazing is then applied. This consists of 125lbs. of white glass without lead, 25lbs. of borax, 20lbs. of soda in crystals, all pulverized together and vitrified by fusion, then ground, cooled in water, and dried. To 45lbs. of this mixture 1lb. of soda is to be added; the whole mixed in hot water, and when dry, pounded. A portion of this powder is sifted finely and evenly over the internal surface of the vessel while the first coating is still moist. The vessel is dried in a stove at the temperature of 212°: next heated gradually in a kiln or muffle until the glaze fuses. The vessel is then taken out and glaze powder is dusted over the glaze already in fusion, and the vessel is again heated. This makes the enamel smoother and sounder than can be effected by a single application.

In consequence of Messrs. Kenrick of West Bromwich sending into the market enamelled saucepans of cast-iron, Messrs. Clarke instituted legal proceedings against them; but they were not able to maintain their patent right in a court of law.

Dr. Ure gives the following dimensions for an oven or muffle used for coating metals with enamel:—"The outside 8 feet square with 14-inch walls; the interior muffle 4 feet square at bottom, rising 6 inches at the sides, and then arched over; the crown may be 18 inches high from the floor; the muffle should be built of fire-brick $2\frac{1}{2}$ inches thick. Another arch is turned over the first one, which second arch is 7 inches wider at the bottom, and 4 inches higher at the top. A 9-inch wall under the bottom of the muffle at its centre divides the fire-places into two, of 16 inches wide each, and 3 feet 3 inches long. The flame of the fire plays between the two arches and up through a 3-inch flue in front, and issues from the top of the arch through 3 holes about 4 inches square. These open into a flue 10 × 9 inches, which runs into the chimney.

"The materials for the enamel body (ground flint, potter's clay, and borax) are first mixed together and then put into a reverberatory furnace, 6 feet 6 inches long by 3 feet 4 inches wide and 12 inches high. The flame from an 18-inch fire-place passes over the hearth. The materials are spread over the floor of the oven about 6 inches thick, and ignited or fritted for 4 or 5 hours, until they begin to heave and work like yeast, when another coating is put on the top, also 6 inches thick, and fired again; and so on the whole day. If it be fired too much, it becomes hard and too refractory to work in the muffles. The glaze is worked in an oven similar to the above. It may be composed of about one-half borax and one-half of Cornish stone in a yellowish powder procured from

the potteries. This is fritted for 10 hours and then fused into a glass which is ground up for the glaze."[1]

Before concluding this article we must notice the art of enamelling by the lamp, by which small articles are modelled from tubes and rods of glass, and of enamel of various sizes and colours.

The enameller's table is represented in Fig. 862, arranged for four workmen. Below is a large pair of double bellows D, set in action by the foot of one of the men for the purpose of producing a blast from a tube, which acting on the flame of each lamp after the manner of a blowpipe, lengthens it and contracts it into a narrow point, the heat of which is very great. Below the table, and in its thickness, are

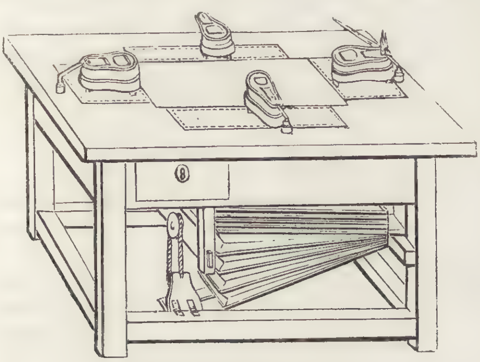


Fig. 862. ENAMELLER'S TABLE.

grooves covered with parchment, which serve to conduct the blast to glass tubes placed opposite each lamp. These tubes or blowpipes A A are of glass, curved at their upper ends so as to direct the blast into the middle of the flame; and they are adjusted by being held in a perforated cork, which exactly fills and closes the hole in the table. When only one person is at work, he sits before the lamp, which is close to the pedal of the bellows, all the other blowpipes being removed and the holes closed with corks. A shade of tin plate is placed over the flame to shield the man's face from the heat and glare, the tip of the flame being left visible; and by day the apartment is made obscure, because the man can work with more precision by the light of his lamp than by the mixture of artificial and natural light. When at work, he holds in his left hand the work to be executed, or the iron or brass wires which serve to support the figure: he then conducts with his right hand the thread or bead of enamel softened by the flame of the lamp.

The manipulations of the enameller cannot well be described. They are the result of much practice, which ought to be directed by good taste. The glass and enamelled toys which are usually sold, are sadly deficient in taste, however much we may admire the manual skill with which they are produced. As an example of this kind of work, suppose the enameller is about to form a swan. He takes a tube of white enamel, closes one end of it with the flame of the lamp, and when sufficiently heated, he blows it into a kind of bottle, to which he gives the shape of the body of the bird: he then lengthens and bends the neck, forms the head, the beak and the tail; after which, with a solid rod of enamel of the proper colour, he makes the eyes; lastly he opens the beak, forms the wings and feet, and the rude resemblance of a swan is finished.

Far more beautiful and satisfactory is the production of that elegant substance known as *spun-glass*, which the enameller makes in the following manner:—He takes a slip of plate-glass and makes it red hot: he then draws it out into a thread with pincers and attaches it to a reel, which he moves rapidly round, holding the slip of glass all the time in the point of the flame. In a short time a skein of glass is formed of great fineness and of the lustre of satin. By using rods of different colours the glass threads may be varied in a beautiful manner. A tuft of spun-glass fixed upon a point upon the prime conductor of an electrical machine in action is a striking object.

The enameller also makes artificial eyes, and if skilful he will so imitate the colours of the natural eye that it is difficult to distinguish it from the real one in a person wearing it.

The reader who desires a more intimate acquaintance with this subject, is referred to the works quoted below, which we have consulted in the preparation of this article.[2]

ENCAUSTIC TILES. See TILES.

ENDOSMOSE and EXOSMOSE. See CAPILLARY ATTRACTION.

ENGINE, a compound machine, including one or more of the mechanical powers, as levers, pulleys, screws, &c. Its object is to raise, cast, or sustain any weight, or produce any effect which could not otherwise be readily accomplished. The word is said to be derived, through the French, from the Latin *ingenium;* because of the ingenuity required in the contrivance of engines to increase the effect of moving powers.

The word MACHINE also signifies anything used to augment or to regulate moving forces or powers; or it is any instrument employed to produce motion, so as to save either time or force. The word is derived from *μηχανή, machine, invention, art;* and it is therefore properly applied to any agent in which these are combined, whatever may be the strength or solidity of the materials of which it is composed. The term *machine*, however, is commonly restricted to a certain class of agents which hold a middle place between TOOLS or INSTRUMENTS and the more complicated and powerful ENGINES.

ENGINEER AND ENGINEERING. Engineer is a term applied to those who are employed in devising or forming engines or machines, and in directing their applications. The duties of the engineer are divided

(1) Supplement to Dictionary of Arts, Manufactures, &c., 1844.

(2) "Nouveau Manuel complet de la Peinture sur Verre, sur Porcelain et sur Email," par M. E. F. Reboulleau, 18°. Paris, 1844. Published in the collection of the Manuels-Roret.—"Dictionnaire Technologique," Article, Email, and the article Enamelling in Brewster's Edinburgh Cyclopedia. In the 55th vol. of the Transactions of the Society of Arts, will be found a paper by Mr. Wynn, "On the Preparation of Enamel Colours and Fluxes, and the Vehicles for laying them on with."

into *military* and *civil*. The duties of the military engineer (since everything relating to the service of artillery is now confided to a particular corps) comprehend the construction of fortifications, both permanent and temporary, including the trenches and batteries required in sieges; also of barracks, magazines, and other works connected with war. In France, the title of engineer is given to those who are engaged in trigonometrical surveying and in the practice of naval architecture. Thus the French have a corps of *ingénieurs géographes*, of *ingénieurs d'hydrographie*, and of *ingénieurs de marine*.

Military engineering will not occupy our attention in this work; but the various important branches and ramifications of civil engineering will be considered under their respective heads. The profession of the civil engineer, as defined in the Charter of Incorporation of the Institution of Civil Engineers, London, is, "The art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks, for internal intercourse and exchange; and in the construction of ports, harbours, moles, breakwaters, and lighthouses; and in the art of navigation by artificial power for the purposes of commerce; and in the construction and adaptation of machinery; and in the drainage of cities and towns." Civil engineering is both a science and an art: as a *science*, it includes the general principles of mechanics and construction; shows how we may ascertain the strains to which a structure is exposed; the dimensions and proportions which should be given to its several parts, so as to be able to resist such strains without injury. As an *art*, civil engineering shows how scientific principles may be applied to the construction of works, and how used and modified so as to meet the difficulties which constantly arise in practice.

The civil engineer, being concerned in almost every kind of construction, ought to be a highly accomplished man of science; and, indeed, there are few men in any profession who can command so large an amount of scientific and practical knowledge as the civil engineer. The following classified arrangement[1] of the several branches of civil engineering, with their subdivisions, will not only serve to show the extent of the subject, but will guide the student in pursuing a systematic scheme in the attainment of his professional knowledge.

Synopsis of the Science of Civil Engineering.

I. MENSURATION.

I. Surveying.—1. Description of instruments; their use and adjustment. 2. Surveying in general. 3. Trigonometrical surveying. 4. Hydrographical surveying. 5. Mining surveying.

II. Levelling.—1. Levelling instruments; their use and adjustment. 2. Practice of levelling. 3. Measuring heights with the barometer.

III. Drawing and Plotting.—1. Instruments for drawing and plotting; their use. 2. Plotting surveys, and making plans. 3. Plotting levels and making sections. 4. Preparing parliamentary plans and sections. 5. Preparing working and contract plans and sections. 6. Preparing detail drawings of works (bridges, &c.). 7. Making mechanical drawings. 8. Principles of projection, perspective, and shadows.

IV. Estimating.—1. Taking out quantities from drawings. 2. Measuring quantities from the works themselves. 3. Measuring artificers' work. 4. Calculating, measuring, and valuing earthwork. 5. Estimating value or cost of works.

V. Setting out Works.—1. Centre-lines and side-widths of railways, roads, canals, &c. 2. Setting out bridges, viaducts, walls, &c. 3. Setting out tunnels and driftways.

II. GENERAL CONSTRUCTION.

I. Statics.—1. Composition and resolution of pressures. 2. Moments of pressures. 3. Parallel pressures, and the centre of gravity.

II. Stability of Structures.—1. General conditions of stability. 2. Stability of polygonal framings. 3. Equilibrium of arches. 4. Stability of abutments and piers. 5. Stability of retaining walls. 6. Equilibrium of suspension bridges.

III. Strength of Materials.—1. To resist a tensile and crushing strain. 2. Elasticity and elongation of bodies subject to a tensile or crushing strain. 3. When subjected to a transverse strain. 4. Elasticity and deflexion of bodies subjected to a transverse strain. 5. To resist torsion.

IV. Materials employed in Construction.—1. Metals. 2. Timber. 3. Natural stones. 4. Artificial stones, including bricks, concrete, and the various cements used in masonry. 5. Materials for earthworks, such as embankments, puddled banks, dams, &c. 6. Materials for roads and pavements. 7. Materials for covering roofs.

V. Different Kinds of Construction.—1. Brickwork. 2. Masonry. 3. Forming Foundations. 4. Carpentry.

VI. Auxiliars employed in Construction.—1. Scaffolding, fixed and travelling. 2. Centerings. 3. Coffer-dams.

III. MECHANICS, OR CONSTRUCTION OF MACHINERY.

I. Dynamics.—1. Vis viva, momentum, and work. 2. Motion; uniform, accelerated, or retarded; gravitation. 3. Collision and impact of moving bodies. 4. Motion down inclined planes and curves. 5. Motion about fixed centres; centres of percussion, oscillation, and gyration.

II. Moving Forces.—1. Water as a mechanical agent. 2. Air as a mechanical agent. 3. Animal strength as a mechanical agent. 4. Heat as a mechanical agent; the steam-engine.

(1) From Mr. Law's "Rudiments of Civil Engineering," published in Weale's Rudimentary Series. 1850.

III. Resistances to Motion.—1. Friction. 2. Resistance of the medium through which the body moves.

IV. Theory of Machines.—1. Elements of machinery. 2. Teeth of wheels, racks, and pinions. 3. Transmission of work by machinery. 4. Determining the modulus of a machine in motion. 5. Mechanical expedients for transmitting or changing motion. 6. Proportioning the strength and dimensions of machinery.

V. Machines employed in Engineering.—1. Machines employed for transporting and raising materials, such as crabs, cranes, dredging-machines, &c. 2. Machines employed in actual construction, such as pile-driving engines, excavating machines, pumps, diving-bells, pug and cement-mills, &c. 3. Machines for working upon materials, as lathes, boring, planing, mortising, riveting, and screw-cutting machines, saws, &c. 4. Implements and tools for excavating, boring, working in wood, metals, stones, &c.

IV. SPECIAL CONSTRUCTION.

I. Common Roads.—1. Principles which should control the selection of route. 2. Laying out roads, and arrangement of gradients. 3. Construction of roads. 4. Draining roads. 5. Repair of roads. 6. Protecting their surface by different kinds of pavement.

II. Railways.—1. Principles which should determine the route, and the general arrangement of the curves and gradients. 2. Different systems of haulage; the locomotive, the atmospheric, and the rope. 3. Of the general construction of the railway. 4. Of the permanent way; different forms of rails, switches, &c. 5. Of draining the line, and maintaining the slopes and permanent way. 6. Arrangement of termini and stations. 7. Construction of engines and carriages. 8. System of working the line.

III. Canals.—1. Principles which should determine the choice of the line of a canal. 2. Arrangement of levels; number of locks, and form of section. 3. General construction of canals. 4. Arrangement of locks; means of saving water, and obtaining feeders. 5. Methods of propulsion, or towing, and resistance on canals. 6. Construction of aqueducts. 7. Repair and preservation of canals.

IV. Harbours and Docks.—1. On the construction of piers, breakwaters, and quay walls. 2. On the means of deepening harbours, by dredging or excavation. 3. Selection of site for docks, and their arrangement. 4. Construction and arrangement of locks, cast-iron and timber gates, sluices, &c. 5. Construction of dock walls.

V. Bridges.—1. Selection of site, and determination of the kind of bridge. 2. Construction of stone and brick bridges. 3. Construction of iron and timber bridges. 4. Construction of suspension bridges. 5. Construction of railway viaducts. 6. Of forming the foundations of bridges.

VI. Tunnels.—1. Determination of the form and dimensions of the tunnel. 2. Method of excavating and securing the ground. 3. Sinking shafts, and driving headings or drift-ways. 4. Method of draining the tunnel. 5. Subaqueous tunnels.

V. HYDRAULIC ENGINEERING.

I. Hydraulics.—1. The science of hydrostatics. 2. Hydrodynamics. 3. Pneumatics.

II. Drainage and Irrigation.—1. Drainage of open country and agricultural districts. 2. Improvement of outfall, and diversion of water from other districts. 3. Surface draining; catch-water drains, and under draining. 4. Drainage of bogs and marsh lands. 5. Of *warping* up, and reclaiming lands from the sea and rivers. 6. Drainage of towns. 7. Form, dimensions, and declivity proper for sewers. 8. Of the collection and disposal of the sewage.

III. Supply of Water to Towns.—1. Principles which should guide the choice of the means of supply. 2. Different sources of supply; from the water-shed of the country, from springs and Artesian wells, or from large rivers. 3. Means of estimating the quantity required, and of ascertaining the probable supply and the quality of the water. 4. Systems of supply; the *constant* or high-pressure system, and the intermittent. 5. Selection of site for reservoirs. 6. Construction of reservoirs. 7. Contrivances for raising the water to the level of the high reservoirs. 8. Of the means of filtering and purifying the water, and of the construction of the filter beds. 9. Of the motion of water in pipes, and their discharge.

IV. Marine Engineering.—1. Action of waves and currents; their modification by the contour of the shore, and the depth of water. 2. Their action on the shore, on beaches, on vertical, sloping, and curved walls, and generally on any obstacle. 3. On the *régime* of coasts, and their preservation. 4. Construction of sea-walls, embankments, breakwaters, piers, and other structures exposed to the action of the sea, more particularly as regards their form. 5. Principles which should determine the selection of the site for a harbour, and the arrangement of its form. 6. On the causes which produce shoals and bars. 7. Means of keeping harbours free from such obstructions, or of removing them where already existing. 8. On the improvement of harbours and sea channels.

V Improvement of Rivers.—1. On the tidal wave at the mouth of rivers, and its modification in passing up the river. 2. Principle of the conservation of tidal force. 3. On the antagonist agencies of the tide and land waters in rivers, and the means of determining which of these should be assisted; of the *régime* of rivers. 4. On the form of the shore-line of rivers, and their improvement. 5. Of the junction of rivers. 6. On the velocity of the stream; its scouring and transporting power compared with the nature of its bed. 7. Effects of projections, irregularities, and obstructions, such as dams and weirs. 8. Of the formation and removal of shoals; their causes; of artificial scouring and sluicing. 9. Of the shoals formed at the mouths of rivers; their cause and prevention.

VI. SCIENCES COLLATERALLY CONNECTED WITH ENGINEERING.

I. Somatology, or the properties of matter.
II. Chemical Philosophy.
III. Geology and Mineralogy.
IV. Natural History.
V. Physical Geography and Hydrography.
VI. Mathematics.
VII. Acoustics.

Of all these sciences a certain amount of knowledge is required by the civil engineer; but of some more than others, depending, in a great measure, upon those particular branches of the profession to which he may more exclusively direct his attention.

ENGRAVING. The process of engraving is one in which the fine arts and the useful arts are equally brought into requisition. In the first place, there is the painting or finished drawing of which copies are to be made; this is the work of an individual mind—the result of the labour of individual hands: the genius of the artist has brought it into existence, and it is stamped at once, by the ideality displayed therein, as belonging to the fine arts. In the second place, there is the faithful copy, wrought out by the graver's tool on a substance from which numerous impressions can be taken: this is no longer an individual work, but one of a multitude; it is capable of being carried on simply by a clever use of tools in the hands of faithful copyists. Observation and imitation are needed, as well as a great degree of skill and taste in transferring the subject to the new material, but original ideas are not required: this, therefore, must of necessity be ranked as a useful art—useful, as widely diffusive of the pleasure conveyed by the fine arts; and likewise useful, as affording a field of remunerative labour to thousands of individuals who may be constitutionally unfitted for other employments.

But while engraving must thus take its place among the useful arts, yet it must not be denied that in order to have the true spirit of the subject conveyed to an engraving, something more than ordinary skill and successful imitation is demanded of the engraver. It has been well remarked by a tasteful writer,[1] that "the engraver is to the painter, what the translator is to the author. As it is impossible to give a spirited translation of a work of genius without a portion of the author's fire, so it is essential to a good engraver that he should feel and understand the character of the original, and be initiated into the art of drawing, that his copy may at once be correct and spirited." But for this gift displayed in the works of many of our best engravers, we should still fail of the enjoyment the art is calculated to produce in the faithful rendering of the pictures of the first masters, and the multiplying of such instructive specimens in our various homes.

The art of engraving is of extreme antiquity. If it cannot with any certainty be traced to antediluvian times in the case of Tubal-cain, the son of Lamech, who is spoken of as "an artificer in brass and iron" yet there are distinct traces of it in the patriarchal age, for carved images were found in the family of Abraham, and these, if we may judge by analogy with the most ancient remains of carving extant, were merely rude outlines on a flat surface, and therefore bore a strong resemblance to engraving. During the sojourn of the Israelites in Egypt they probably exercised this art after the Egyptian manner, which consisted of hieroglyphical figures, cut in outline on metal and stone. But during their wanderings in the desert, two men (Bezaleel and Aholiab) were specially set apart to "devise curious works in gold, silver, and brass, and in the cutting of stones to set them, and in carving of wood," for the service of the tabernacle; and of them it is declared that God "filled them with wisdom of heart to work all manner of work of the engraver." Exod. xxxv. 35.

The rude methods of Egypt are supposed to have been adopted by the Phœnicians, and thus to have been conveyed to Greece, where, in Homer's time, the art of engraving had considerably advanced. One of its earliest uses in that civilized nation was in the delineation of maps on metal plates. Specimens of the art as practised in Etruria are thought to be of a very remote antiquity, and are quite capable of being printed from, as has been proved by actual experiment. But the idea of filling in these rude outlines with ink, and taking impressions from them, was reserved to later times. Thus, the ancients just missed a discovery which now forms the principal element of our progress. This is the more remarkable when we remember that they knew how to take impressions of seals and stamps in wax, clay, and other soft bodies, and that they seem to have had stamps with separate letters engraved upon them.

The art of engraving comprises three great divisions, for which appropriate technical terms have been found by referring to the Greek language. Copper-plate engraving is named *Chalcography*, from the Greek words signifying *copper*, and *I inscribe;* wood-engraving, *Xylography*, from *wood*, and *I inscribe;* engraving on stone, *Lithography*, from *a stone*, and *I inscribe*.

The first of these, or the art of engraving on copper, and taking impressions from the engraved plates, is ascribed to a native of Florence, named Finiguerra, who flourished in the fifteenth century. He was a skilful workman in a species of handicraft then largely practised, namely, the engraving of church ornaments and other articles, and filling the engraved parts with a black composition of silver and lead. This was called working *in niello*, and had a good effect, as may be seen by remaining specimens. It is said that Finiguerra having on one occasion cast some melted sulphur on his engraving, to try its effect previously to putting on the black composition, observed, on removing the sulphur, that some dust and charcoal which had gathered in the hollows gave an impression of what he had engraven. On this he tried the effect of moistened paper, pressed down on the engraving with a roller, and met with complete success. Other goldsmiths and engravers followed

(1) Allan Cunningham.

in the steps of Finiguerra, and this important discovery soon became widely diffused. Throughout the sixteenth century improvements in this art were numerous in Italy, and the skill of Marc Antonio Raimondi, and the students of his school, raised the fame of the Italian engravers to a high pitch.

Meanwhile Germany was making rapid progress in the same art, first practised in that country by Martin Schongauer, and carried to eminence by Albert Durer and his followers. The artists of the Flemish and Dutch schools, together with the skilful engravers of France, also contributed to spread throughout Europe the triumphs of this interesting branch of knowledge.

The art of engraving was early known in England. Printing was discovered during the first half of the fifteenth century, and engraving quickly followed, as is proved by Caxton's "Golden Legend," printed in 1483, and ornamented with numerous cuts. Copper-plate engravings appeared in Vesalius's "Anatomy," printed in England, in Latin, in 1545. These were the work of Thomas Geminus, or Geminie, the first English engraver of whom we have a distinct account. A translation of the work by Udal, dedicated to Edward VI., contained in the preface the following passage: "Accepte, jentill reader, this Tractise of Anatomie, thankfully interpreting the labours of Thomas Gemini the workman. He that with his great charge, watch, and travayle, hath set out these figures in pourtrature, will most willingly be amended, or better perfected of his own workmanship if admonished." The first maps of English counties were engraved by Christopher Saxton in 1579.

In the reign of Charles I. an engraver-royal (Voerst, a native of Holland) was appointed, and the art received much encouragement from the king and the Earl of Arundel. The celebrated Vandyke assisted its progress by his vigorous and expressive etchings; various improvements were made; Prince Rupert discovered *mezzo-tinto*, and for a brief period engraving flourished greatly; but the bad taste and dissolute manners of the succeeding reign checked its progress, and had the worst effect on the art. Its subsequent revival and brilliant success in the hands of Hogarth and his cotemporaries, and its high eminence at the present day, present too extensive a field to be traversed here. Suffice it that we describe some of the processes of this interesting art as now practised.

Supposing a copper-plate engraving to be begun and carried on without the aid of etching, it is as follows:—A plate of copper is first prepared, smooth, and free from all imperfections, very level, and highly polished. On this plate the outlines of the landscape or subject to be engraved must be accurately drawn. To this end the copper-plate is first heated in an oven till it attains a sufficient uniform heat to melt white wax, a piece of which is rubbed over it, and allowed to spread in a thin layer till the whole surface is equally covered, after which it is left in a horizontal position till the wax and plate are cold. In the interval a careful tracing of the original design is made with a black-lead pencil on thin tracing paper, and this is afterwards spread over the waxed surface of the plate, with the lead lines in contact with it. The tracing being secured in this position, heavy pressure is applied, the effect of which is to transfer the lead lines from the paper to the wax. The engraver now takes a fine steel point, and (the tracing-paper being removed) goes over the subject lightly, so as just to penetrate the wax and touch the copper. By this means a perfect and delicate outline is drawn upon the plate, and when the wax is melted off, the subject is ready to be proceeded with and finished off, according to the skill and manual dexterity of the engraver. These are not within the powers of description; but we may briefly state that the principal instrument employed is the *graver* or *burin*, made of steel, and ending in an unequal-sided pyramidal point. This instrument is held in the hand at a small inclination to the plane of the copper, and is pushed forward in the direction required, to cut the lines on the plate. See Fig. 863. Should the lines be cut too

Fig. 863.

deeply, a smooth tool, about three inches long, called a *burnisher*, is employed to soften them down, and to burnish out scratches in the copper. But the graver, in ploughing furrows in the surface of the copper, raises corresponding ridges or burrs; these have to be scraped off by another tool, about six inches long, called a *scraper*, also of steel, and having three sharp edges. A woollen rubber is also occasionally used, with a little olive oil, to clear the face of the plate, to show the progress of the work, and to polish off the burr. Writing-engravers also use a leather bag, filled with sand, as a cushion, to support the plate during the progress of the work. Where a series of parallel lines are wanted, in architectural subjects or for skies, manual labour can be dispensed with, and a ruling machine substituted, which acts with most complete effect. The above method was the ordinary one in former times, and is still continued in the engraving of letters, silver plate, &c., but since the discovery of etching it has almost universally given place to that freer and more expeditious process.

Besides engraving, properly so called, there are several varieties known, as *etching*, *mezzo-tinto*, *aquatinta*, &c.

Etching now forms a most important part of the engraver's art, for nearly all his productions are commenced, and, to a considerable extent, carried forward by its aid. It is the process of corroding with aquafortis the lines of a drawing, traced out with an etching needle on the copper-plate, over which has been previously placed what is called an *etching ground*, namely, a preparation of bees'-wax, Burgundy pitch, &c., incorporated over the fire, and capable of resisting the action of the aquafortis. The following composition forms a good etching ground:—two ounces of

white wax, half-an-ounce of Burgundy pitch, half-an-ounce of black pitch, and two ounces of asphaltum. The ingredients, with the exception of the asphaltum, are put into a crucible and melted over a slow fire. The asphaltum meanwhile is reduced to a fine powder, and is stirred into the composition by degrees. When the substances are all intimately blended, the composition is poured into cold water, and worked into balls about the size of a walnut, which are tightly and smoothly tied up in small pieces of plain worn silk. When the plate is to be prepared for etching it must first be heated with an equal heat throughout, by holding it by means of a hand-vice over a stove, or in an oven. A bit of folded paper will save the plate from injury at the points where the vice presses. No more heat is required than is sufficient to melt the composition, or etching ground, which is now applied by rubbing one of the silken balls over the plate, the warmth of which causes the substance to ooze through the silk. The ground is then equalised by rubbing with a dauber. This is variously contrived, but a simple kind is made of lamb's wool, properly washed and dried, and then tied up in soft fine muslin in the shape of a flattened ball. Outside this must be smoothly stretched and tied a piece of black silk, not new or twilled, otherwise it will cause the surface to be unequal. When the daubing is completed, and the etching ground smoothly and equally distributed, the copper-plate is held, face downwards, over the flame of a wax candle, or of two or three candles tied together, until the whole surface of the etching ground is smoked to blackness. It is then ready to receive the design, which is first made in outline with a black-lead pencil on a piece of thin even paper, and then placed face downwards on the smoked surface. The whole is then passed through the roller-press used for printing copper-plates, which transfers an impression of the outline to the ground. After this the design is completed with the etching needles, a very fine point being used for the more distant and delicate parts, and a broader one for the nearer and bolder objects. These needles remove the wax composition or etching ground from the copper wherever they pass, and slightly scratch the surface of the plate, thus exposing it to the full action of the acid during the subsequent process of biting-in. To prepare for this, a border of wax half an inch high is put round the plate to form a trough for the acid. This is called *banking-wax,* and is made of bees'-wax, common pitch, Burgundy pitch, and sweet oil, melted in a crucible, and poured into cold water: when cold it is quite hard, but on immersion in warm water it becomes soft. The wax having been made to surround the copper-plate, and being sufficiently hardened, the next operation is to pour in nitrous acid, reduced with water to the proper strength, (usually about one part acid to four parts water,) which experience alone can teach. Its action on the copper is apparent in the rising of innumerable bubbles. When the acid has been on a sufficient time to corrode the fainter and more distant parts of the subject, it is to be poured off, the plate washed with water, and left to dry. These fainter parts are then to be varnished with a mixture of lamp-black and Venice turpentine, applied with a camel's-hair pencil, which stops the further action of the acid on those parts. Hence the mixture is called *stopping-ground.* When it is dry the acid is again poured on, and the action renewed on the bolder parts of the subject. This stopping-out and biting-in can be repeated as often as the nature of the subject or the taste of the engraver may suggest, so that many gradations of tint can be obtained. After this the waxen border is removed by heating the plate, and by a little further warming the etching ground can also be wiped off with a rag moistened with olive oil. The work is now complete, unless it be wished to finish it more highly with the graver. This is frequently done, for, as we have already noticed, almost every engraving at the present day is partly etched. Etching points or needles resemble common needles, fixed in handles four or five inches long. Some are, however, made of an oval form, in order to produce broader lines. What is called the *dry-point* is nothing more than the common etching needle brought to a very fine point, for the purpose of cutting or scratching the more delicate lines of skies, &c. The dry-point does not cut the copper clean out, but raises a slight ridge or burr, which is ordinarily removed with the scraper, but which may in some cases be left on with fine effect. This is the case with Rembrandt's etchings, in which the burr was left on till it wore away in printing. Early impressions of his etchings, in which this peculiarity is visible, are therefore much valued. Imitations of chalk and pencil drawings are sometimes produced by etching on soft ground, but this practice has been greatly superseded by that of lithography. Etching on steel is performed in the same way as on copper, the steel also yielding a greater number of good impressions. A species of etching is also employed in the representation of medals, a machine of peculiar construction being brought into operation. For etching on glass, a ground of bees'-wax is laid on, and the design is traced with the needle as before. Sulphuric acid is then poured on, and fluor spar sprinkled upon it, or fluoric acid may be at once used: this is allowed to remain four or five hours, and is then removed with oil of turpentine. Etched imitations of chalk drawings of the human figure, called engravings in *stipple,* have a very soft effect, but are inferior to engraving. In this variety the whole subject is executed in dots without strokes on the etching ground, and these dots are bitten-in by aquafortis. Again, these dots may be harmonized with a little hammer, in which case the work is called *opus mallei.* In the method known as *mezzo-tinto* a dark barb or ground is raised uniformly by means of a toothed tool, and the design being traced, the light parts are scraped off from the plate by fitting instruments, according to the effect required. In *aquatinta* the outline is first sketched, and then a sort of wash laid on with aquafortis upon the plate, producing the effect of Indian-ink drawings. Copper-plate engraving, therefore, in all its varieties, opens a wide field for

the taste and industry of those who would perpetuate and multiply valuable works of art in the several styles best suited to their respective subjects.

Steel-engraving is performed in the same way as copper-plate engraving, with the exception of some slight modifications in the use of acids. The improved presses used in both kinds of engraving are due to Mr. Jacob Perkins, who may be said to have established steel-engraving by his invention of decarbonizing the plate, so as to make it fit to be engraven on, and also by his interesting method of multiplying impressions on steel-plates. Mr. Perkins's method of transfer-engraving originated in the transfer processes employed in engraving the copper cylinders used in calico-printing. The subject intended to be multiplied is first engraved either by hand or mechanically, or the two may be combined, in the best style of art on a plate of soft steel: the plate is then hardened. A decarbonized steel cylinder is next rolled over the hardened plate by means of powerful machinery, until the engraved impression appears in relief, the hollow lines of the original being raised on the cylinder. The roller is then reconverted to the condition of ordinary steel, and hardened, after which it can be used for returning the impression to any number of decarbonized plates, each of which is of course an exact counterpart of the original. It is said that each of these plates when hardened would give 150,000 impressions without being materially worn. The original plate thus serves only to give one impression to the transfer roller, which in its turn is used to produce any number of plates. Should any accident happen to the transfer roller, another impression can easily be taken from the original plate.

In order to decarbonize the plates they are placed in a vertical position in cast-iron boxes not less than $\frac{3}{4}$ inch thick, and surrounded on all sides by a stratum of iron-filings not less than $\frac{1}{2}$ inch thick; the boxes are then placed in a furnace, and after being heated are cooled very slowly by stopping up all the air passages, and covering the boxes with cinders to the depth of 6 or 7 inches. The decarbonized plates are reconverted into steel by enclosing them in boxes as above, and surrounding them with fine charcoal made from leather; they are left at the proper heat for from 3 to 5 hours, and on being taken out are immediately plunged in a vertical position into cold water.

Wood-engraving (*Xylography*) is said to have had its origin in China, the birth-place of many other valuable inventions, and to have been due to the peculiar structure of the Chinese language, in the writing of which a separate symbol is used for each idea, and words are not made up, as with us, by a combination of letters. The number of these symbols or characters is therefore so vast that it would be almost impossible to print their books with movable types. Their method of printing is therefore as follows: the work to be printed is carefully transcribed upon transparent paper, only one side of which is written on. The sheets are then glued down upon wooden tablets, and all the wood is cut away except that covered by the lines of the writing. From these raised wooden lines impressions are taken. This practice is of ancient date in China, and some of those who have bestowed research on the matter are inclined to fix it about A.D. 930. As far as it is now possible to trace the introduction of wood-engraving into Europe, it would appear that the Venetians, in their commerce with the Chinese, early learned this art, and practised it before it was known to other European nations. But the art was eagerly acquired by Germany and the Low Countries, and in 1433, or thereabouts, they carried on a considerable commerce in playing-cards and prints of saints. At that time the engraver on wood was called *Formschneider*, or figure-cutter, a term still in use. The little prints of saints were rudely executed, and had a great sale among the common people. In Germany they were called *Helgen*, or *Helglein;* in France, *Dominos.* They were at first sold separately, and thus were soon dispersed and lost; but after a time they were pasted into religious books for the sake of preserving them, and thus probably originated the custom of illustrating books with engravings. From that time the art made decided progress. Block-books, as they are called, made their appearance. These were books in which the productions of the wood-engraver were simply collected in the form of volumes, some of which are still extant. One of the earliest, called the *Biblia Pauperum*, or Bible of the Poor, consists of 40 leaves, small folio, printed from the same number of engraved blocks of wood, on one side of the paper only. These prints are placed two by two, facing each other, so that by pasting their backs the book has the appearance of being printed in the usual way on both sides. The use of printed characters in books is closely connected with the origin of wood-engraving, but the exact time of the invention is a disputed point. One of the most generally received accounts of this discovery is thus given by an old German chronicler:—

" At this time (about 1438), in the city of Mentz, on the Rhine, in Germany, and not in Italy as some have erroneously written, that wonderful and then unheard-of art of printing and characterising books was invented and devised by John Gutenberger, citizen of Mentz, who, having expended most of his property in the invention of this art, on account of the difficulties which he experienced on all sides, was about to abandon it altogether; when by the advice and through the means of John Fust, likewise a citizen of Mentz, he succeeded in bringing it to perfection. At first they formed or engraved the characters or letters in written order on blocks of wood, and in this manner they printed the vocabulary called a 'Catholicon.' But with these forms or blocks they could print nothing else, because the characters could not be transposed in these tablets, but were engraved thereon as we have said. To this invention succeeded a more subtle one, for they found out the means of cutting the forms of all the letters of the alphabet, which they called matrices, from which again they cast characters of copper or tin of sufficient hardness

to resist the necessary pressure, which they had before engraved by hand." In this latter process the original inventors were greatly aided by Peter Schoeffer, son-in-law to Fust, who shares with the other two in the honours accorded to the worthy citizens of Mentz. An early and celebrated result of the union of typography and wood-engraving was a Psalter printed on vellum by Fust and Schoeffer, at the end of which there is a congratulatory paragraph on the discovery of the art of printing. The large initial letters of this Psalter are beautifully executed and printed in two colours.

The artists of Italy competed successfully with those of Germany, in the prosecution of this interesting art, but attention was recalled to German art by the engravings of Albert Durer and his cotemporaries, during whose time wood-cutting was in high estimation. At the close of the 16th century this art had greatly declined in Germany, but was better understood in France and England than at any previous period. Yet it was reserved to the 18th century to give a powerful impulse to the art in Britain. This was done by Thomas Bewick, who showed, in his "British Birds," a most skilful and effective adaptation of the means his art then afforded of faithfully representing nature. He was undoubtedly the instrument of a great revival in wood-engraving, and led the way in that career of success which has since distinguished the wood-engravers of this country.

The processes connected with wood-engraving chiefly differ from those of copper and steel engraving with respect to the different nature of the material employed. Box-wood is the only kind that can be successfully employed in wood-engraving. American or Turkey box is of large size, but is inferior in quality to our English wood. It should be of a clear yellow colour, as equal as possible over the whole surface, without spots or variations of tint, which mark inequality of growth and consequently of hardness, and which are sometimes quite evident in the impressions taken from such blocks, the whiter portions being softer and more absorbent of ink, and retaining it more tenaciously. The natural hardness and toughness of box, with the poisonous nature of its juices, are of great importance in preserving blocks from the attacks of insects, to which apple, pear, and beech-wood, sometimes used for the purposes of engraving, are naturally liable. But box-wood requires to be well-seasoned, otherwise it is liable to warp and bend. If a block of unseasoned wood be allowed to lie flat for a week or two, it is almost sure to bend upwards at the edges. Blocks of wood, therefore, should always be placed on their side edges when laid by for future use, and in the process of engraving they should be turned over on their faces, in the intervals of the work, or some degree of curvature may be given to them by the warmth of the engraver's hand. When a block becomes slightly concave, and the circumstance is not noticed by the pressman previous to taking an impression, the wood frequently splits. Blocks when smooth and polished are prepared for drawing on, by simply rubbing the polished surface with bath brick in very fine powder slightly mixed with water. When this thin coating is dry it is removed by rubbing the block with the palm of the hand: its only use is to make the surface less slippery. Some artists, previous to beginning their drawing, wash over the surface of the block with flake-white and gum-water, but if the white ground be too evident the effect is confusing to an engraver in the progress of his work, the parts cut being of the natural colour, while the uncut parts are white. "The less that is done to alter the natural colour of the wood," say the best engravers, "the better." Flake-white is also apt to mix with the ink in taking a first proof, and to fill up the finer parts of the cut.

As box-wood is, notwithstanding its hard and compact nature, very much softer than copper and steel, and is, moreover, less equal in density throughout, so the graving tools must be guided in a different manner, and a check must be put on the force with which they are ordinarily sent forward by the palm of the hand. There are four descriptions of cutting-tools used in wood-engraving; and numerous specimens of each, differing in size and degrees of fineness, are kept at hand. Of the four kinds of tools, the first is the graver, differing little from that of the copper-plate engraver, but adapted to the purposes of wood-cutting by having the point ground to a peculiar form by rubbing on a Turkey stone. Eight or nine gravers of different sizes are generally required, commencing with a very fine one, called the outline tool. The upper part A, Fig. 864, is the back, the lower part D is technically called the belly; B is the face of the tool; C, its point. The latter is so extremely fine that the line is scarcely perceptible when the cut is printed; the object being with this tool merely to form a termination or boundary to other series of lines. This tool, in common with others, is fixed in a convenient handle, which, as it is received from the turners, is perfectly circular at the end; but part of this rounded end is cut off after the blade is inserted, in order to accommodate the tool to the flat surface of the block, and also to insure its being ready to the hand in the right position for use when laid aside and then taken up again. Eight or nine gravers, Fig. 865, are required, beginning with the outline tool, and increasing in size and breadth. The engraver also adapts them to his particular purpose, either by making them finer, or by grinding them down to greater breadth, and rounding them slightly at the points. The lower dotted line in

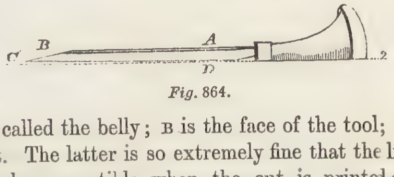


Fig. 864.

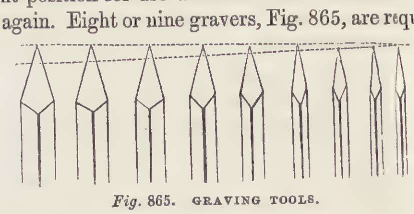


Fig. 865. GRAVING TOOLS.

Fig. 865 shows the extent to which the points are usually ground down. Gravers are used for nearly every description of wood-cutting, occasionally, not even excepting "tinting," the technical term applied to cutting series of parallel lines, which, when engraved, form an even and uniform tint. For this process, however, there is a distinct set of tools, Fig. 866, thinner, and ground to a much more acute angle at the face. These tools, though thin, ought to be sufficiently strong at the back to prevent their bending when used: their

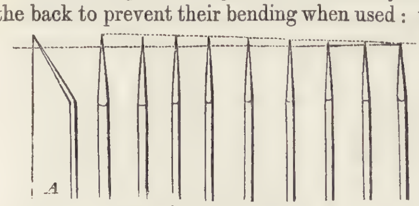


Fig. 866. TINTING TOOLS.

faces, as well as those of the gravers, should also be rather long than short, for they then cut with much greater clearness, and the shaving of wood turns gently over towards the hand, as shown in Fig. 867;

Fig. 867.

Fig. 868.

whereas, when the graver is too obtuse, the shaving, instead of turning aside, coils over before the point of the tool, as in Fig. 868, and hides the pencil-line which the engraver is following. A, Fig. 869, is an

Fig. 869.

example of an obtuse form of tool: this may be converted into an acute tool by grinding down the portion shown by the dotted lines in B. In addition to gravers and tint-tools there are gouges of different sizes, Fig.

Fig. 870.

870, for scooping out the wood towards the centre of the block, and flat tools, or chisels, for cutting it away towards the edges. A form of flat tool, marked C, is to be avoided, as the projecting corners are apt to cut under a line, and give much trouble in plugging, or inserting new wood, on which to replace it.

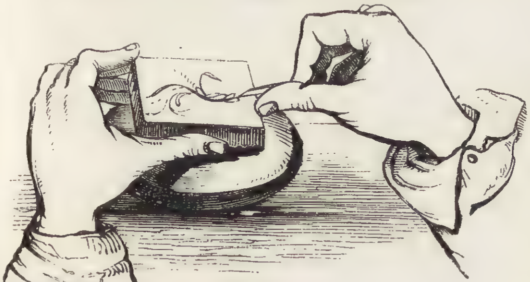


Fig. 871.

The method of holding the graver is different when the material is wood, to that employed in copper and steel engraving. In the latter case, the forefinger is extended on the back of the tool, so as to press the point into the plate. (See Fig. 863.) In wood-cutting this is not necessary, but, on the contrary, the force of the hand has to be checked by the thumb, which in small subjects is rested against the side of the block, allowing the blade to move freely, but ever ready to check it in case of a slip. See Fig. 871. In larger subjects, the thumb accomplishes the same ends by resting on the surface of the block. See Fig. 872.

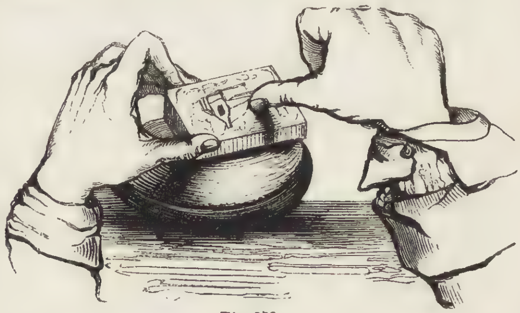


Fig. 872.

Engraving requires delicate and skilful workmanship, and makes large demands on the eyesight as well as on the dexterity of hand of those who practise it. Some parts of the work are generally supposed to require the use of magnifying glasses, and much of it must necessarily be accomplished by lamp-light. The most experienced engravers, however, are slow to recommend the use of glasses to those who can possibly do without their assistance. Young persons commencing the art of wood-cutting seem to imagine that a magnifying glass must of necessity form part of their apparatus. The sort of glass employed is similar to that of watch-makers, and consists of a single lens fitted into a short tube, and rather wider at the part applied to the eye. Such aid should only be sought when sight begins to fail; and even then the glass should at first be of low magnifying power. Various means are employed to protect the eyes from the light, and the face from the heat, of the lamp. One of these consists in the use of a large glass globe filled with water, which is interposed between the lamp and the engraver's block. By the use of these globes one lamp is found sufficient for three or four persons, and each person has a clear and cool light to work by. In damp or frosty weather, the breath of the engraver is apt to injure his work, unless some contrivance be adopted to prevent its playing on the surface of the block. This is usually found in a screen of thin pasteboard or stiff paper, temporarily tied across the mouth and nostrils in such weather. The eyes have their own protection, from a shade which most wood-engravers wear, not only to guard the sight, but also to concentrate the view on the work in hand. Such shades are, however, very objectionable, as they confine hot air close to the eyes, which require for healthy action the free circulation of fresh air.

The pupil in wood-engraving commences with the cutting of parallel lines or tints, straight and waved,

and then proceeds to simple forms in outline, without any shading that is expressed by cross-lines. Such shading is necessarily difficult in a material where all the parts intended to be light have to be cut away, and the dark lines alone remain standing; and consequently in cross-shading the interstices have to be carefully hollowed out, without injury to the lines. Complicated subjects should be long deferred, and never attempted till decided success has attended the simpler efforts.

Lithography, or engraving on stone, is a modern invention, ascribed to a musician named Senefelder, connected with the theatre at Munich, about the year 1800. The term engraving is not truly applicable to the process, as usually carried on; but in Germany a great deal of actual engraving on stone with the burin is practised. The results of this method, however, are so greatly inferior to those of copper-plate engraving, that it is not likely ever to come into general use. The art of taking impressions from drawings made on stone depends on the readiness with which calcareous stone imbibes water, its great disposition to adhere to resinous or oily substances, and the disposition those substances have to combine, and to repel water or any substance moistened with water. Drawings made on a polished surface of calcareous stone with a resinous or oily substance adhere strongly to the stone, and are not at all affected by water poured over it, and which the other parts imbibe readily. But if a resinous or oily body be then passed over the stone, it will adhere strongly to the drawing, and not to the watery parts of the stone.

The drawings, therefore, in lithography, are made with ink and chalk of a soapy nature. The ingredients of the former are tallow-soap, pure white wax, lamp-black, and a small quantity of tallow, all boiled together, and when cool, dissolved in distilled water. The ingredients for the chalk are the same, with a small quantity of potash added during the boiling. After the drawing on the stone is perfectly dry, a very weak solution of sulphuric acid is poured over it, which takes up the alkali from the ink or chalk, and leaves an insoluble substance behind it, while it lowers in a slight degree the surface of the stone not drawn upon, and prepares it for the free absorption of water. Weak gum-water is next applied, to close the pores of the stone, and keep it moist. The stone is then washed with water, and the printing-ink applied in the ordinary way. It then passes through the press; the washing with water and daubing with ink being repeated after every impression. The impressions may be multiplied to a great extent, without any marked failure in the effect. As many as 70,000 copies or prints have been taken from one stone, the last being nearly as good as the first. The work can also be performed with great expedition and economy. Drawings made with the chemical ink on paper prepared with a solution of sise or gum tragacanth can be transferred to the stone, by being merely laid thereon and passed through the press, when the subsequent processes can be carried on, as already described. Copper-plate and steel engravings can be transferred to stone, and worked by power presses, thus lessening the expense, and affording a convenient mode of multiplying maps which may be required in large quantities.

ENVELOPE-FOLDING MACHINE. Among the machines exhibited in motion in the Great Exhibition, Messrs. De la Rue and Company's envelope-folding machine was always surrounded by a crowd of interested spectators; and it is worthy of the admiration which it has excited; for whether we regard the rapidity and precision with which it does its work (folding an envelope every second), or study the anatomy of its structure, we have a striking illustration of the proposition, that whatever merely mechanical operation is performed well by human hands, can be effected much better and far more quickly by a self-acting machine. Through the kindness of the inventors, we are able to lay before our readers a sufficiently minute description of this machine.

As the various motions of this machine are produced by means of cams, it will be necessary to the due understanding of the subject to describe the nature of a cam, and the method by which it is produced.

A Cam is a contrivance in which sliding contact is employed to communicate a velocity ratio, either constant or varying, between two pieces of mechanism. The extent of motion of one of these pieces must be limited, that of the other may or may not be continuous. Thus for example, if one of them be required to move in a short rectilinear path in the manner of a rack or sliding bar, an axis revolving indefinitely in one direction, or with a defined to and fro rotation in both directions, may, by means of a cam, be made to give motion to this bar or rack. If the relation between the speed of movement of the bar and that of the axis be uniform, then the velocity ratio is said to be *constant*. If, however, the speed of the bar does not, in the successive periods of its motion, bear any uniform relation to the velocity of the axis, then the velocity ratio of the two pieces is said to be *varying*.

Let A, Fig. 873, be the centre of motion of a plate, to which an alternating movement of rotation can be given. In this plate a slit *a b* is pierced, having parallel sides, so as to embrace and nearly fit a pin *m*, carried by a bar C D fitted between guides, so as to be capable of sliding in the direction of its length. While the plate revolves in the direction of the arrow, the inner side of the slit presses against the pin and moves it further from the centre A; but when the plate revolves in the opposite direction the outer edge of the slit acts against the pin, and moves it in towards the centre. If the linear velocity of translation of the bar be required to be exactly

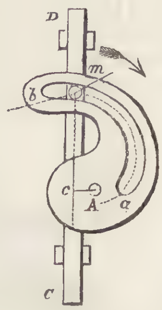


Fig. 873.

equal to the circular velocity of a point c of the plate, then the curve $a\ b$ must be an involute of the circle whose radius is A c. So for other constant velocity ratios, curves can be found which shall fulfil the required conditions.

If the sliding movement of the bar be required to continue during several revolutions of the axis A, the curve ab becomes converted into a spiral or *plane screw*, Fig. 874. Were the rotatory motion of the axis indefinite and in one direction only, the to and fro sliding motion of the bar might be effected by continuing the slit $a\ b$, Fig. 873, in a curve exactly like the first, but inverted in position, so that the summits of the two slits join at b, and their inner ends at a. It is obvious that in such a case the slit must not be carried quite through the plate, but must form a groove in its face only, as in A, Fig. 875.

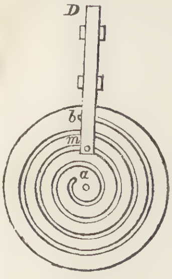


Fig. 874.

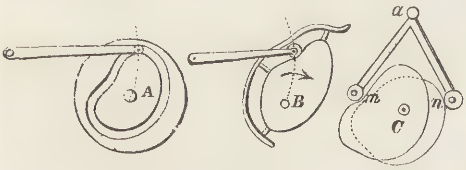


Fig. 875.

Now suppose that the velocity ratio of the two pieces is to vary, so that when a series of points, 1, 2, 3, 4, 5, Fig. 876, in the circumference of the circle C 3, 5, shall have reached in order the point C, the pin in the sliding bar shall be moved into the corresponding positions I, II, III, IV, V. To each of the position points in the circumference of the circle draw tangents, and from the centre A draw circular arcs through the given positions, I, II, III, IV, &c. intersecting the respective tangents, as at $a\ b\ c\ d\ e$. Then a curve drawn through this series of points $a\ b\ c$ will be the curve required; for it is clear that if any point (as 3) of the circle be moved to c, the corresponding point c of the curve will be in the position III, and therefore the pin acted on by this curve will be moved as required: and so for any other pair of positions.

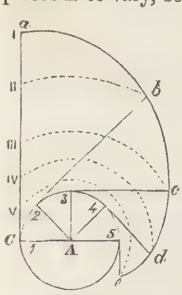


Fig. 876.

When the grooved plate is used, the line thus traced is the centre of the groove, from which the half thickness of the pin must be set off on both sides to give the width of the groove required. But it is obvious, that if the pin be, by the pressure of a spring, or weight, or by other contrivance, made to bear steadily upon the edge of the plate $a\ b\ c\ d\ e$, Fig. 876, the required movement may be obtained. Such a plate acting on an oscillating arm (which is called a *follower*) is shown in Fig. 877. The follower will obviously make one double oscillation up and down during each revolution of the axis.

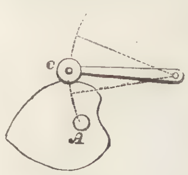


Fig. 877.

Such a cam has its most simple form when no sudden change of velocity is required in the follower, and one complete double oscillation is to be made for each revolution of the axis. The cam then becomes an eccentric circle, as at C, Fig. 878. Here a is the eccentric centre of motion, b the centre of the cam, $a\ c$ the direction of the motion in the follower, which is a roller, whose centre is c. Then $b\ c$ is constant, and the motion given to the follower is the same as if a link $b\ c$ and crank $a\ b$ were employed. This form may be modified, as in Fig. 879, by attaching a pin c to an eccentric disc revolving about a centre a. This pin working in a slotted arm, communicates to it an oscillating motion about its centre b.

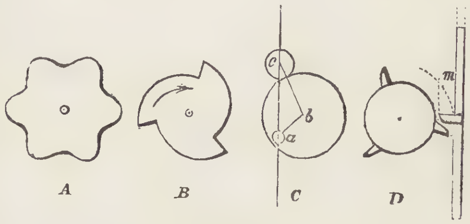


Fig. 878.

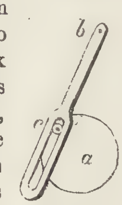


Fig. 879.

When the bar or follower is to make a number of oscillations during each rotation of the axis, the cam may assume the form of A, Fig. 878; or if a series of lifts, each with a sudden return of the follower, be required, the outline of the plate may be like B, Fig. 878. When these lifts are communicated (as to a set of stampers) with intervals of rest between them, the cam becomes a disc bearing projecting teeth or cogs, as at D, Fig. 878. Such teeth or cogs are then called *wipers* or *tappets*.

When the use of a spring or weight to bring back the follower is inconvenient, the grooved plate already described (A, Fig. 875,) may be employed. If the cam revolve always in the same direction, the outside of the curve is required during that portion of the revolution only in which the follower approaches the centre. Its place may then be supplied by a bar or guide fixed to the cam, as at B, Fig. 875. Or the follower may have two arms, as in C, Fig. 875, resting on two distinct cams, placed one behind the other on the same axis, so that when the edge of one cam is retiring, that of the other is advancing. Care must be taken that the distance $m\ n$ between the points of contact of the follower-arms shall be always the same. It is obvious, that by varying the form of the curve for the groove or circumference of the plate, the motion of the follower at the several phases of its oscillation may be regulated at pleasure.[1]

These few remarks may be appropriately wound up with a description of the method by which the main cam

(1) Figs. 873 to 879 are from Professor Willis's "Principles of Mechanism." London. 1841.

of the envelope-folding machine was formed. C, Fig. 880, is the centre of the cam, and C′ the centre of the lever or follower. The extent of motion of this lever is first determined by means of the arc a a', which if prolonged would reach the centre C. The fraction of the revolution of the wheel, *i. e.* the time occupied in the motion of the lever, is also predetermined, and marked out by means of the arc r r'.

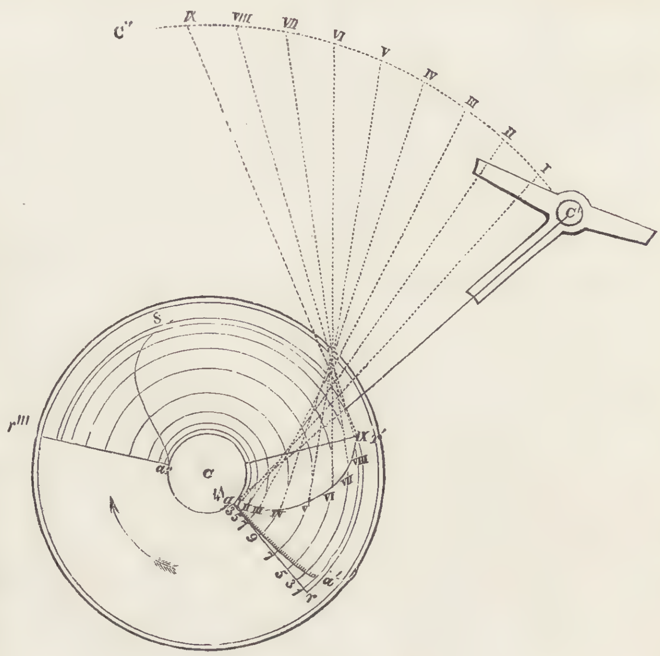


Fig. 880.

With the radius C C′ draw an arc C′ C″, and from C′ set off the portion C IX, corresponding to the angle comprised between the radii r r'. Divide this into any odd number of parts, nine for example, numbered in a direction opposite to that of the motion of the cam, I, II, III, &c. Now by the laws of mechanics, a falling body moves in successive intervals of time through spaces corresponding to the odd numbers, 1, 3, 5, 7, &c., and as it is of advantage to give equal impulses to the machine, the same law is followed in the extent of motion given by the cam to the lever; but if this law were to operate until the end of the motion, a considerable shock would be given to the machine, since the body being set in motion would be moving at its greatest velocity by the time it had completed one revolution. It is therefore arranged that this law shall be maintained up to a certain point, or until the centre of the motion is arrived at, after which, the motion is continued with a velocity constantly decreasing in the same ratio as it before increased. For example, in the nine periods previously determined on,

Period I.	a space is moved through equal to	1
II.	„ „	3
III.	„ „	5
IV.	„ „	7
V.	„ „	9
		—
	or as the square of the times	25
VI.	a space is moved through equal to	7
VII.	„ „	5
VIII.	„ „	3
IX.	„ „	1
		—
	or in the inverse ratio of the squares of the times	41

We therefore divide the arc a a', described by the lever C′ a during its predetermined motion, into 41 spaces, and beginning at a describe from the centre C a circular arc, passing through the zero or starting point of these divisions. In the same way, successive segments of circles are drawn from the centre C, at such distances as to pass through the 1st, 4th, 9th, 16th, 25th, 32d, 37th, 40th, 41st, divisions from a (corresponding to the spaces, 1, 3, 5, 7, 9, 7, 5, 3, 1), and intersecting the radii a r and $a''r'''$. With the radius a C′, placed successively at the intervals I, II, III, IV, &c. on the arc C′ C″, intersect the arcs I, II, III, IV, &c. A curved line a to IX, drawn through these various intersections, is the centre line of one face of the cam. The lever might be made to return immediately to its former position, or to any intermediate position, but in the cam about to be described it is intended to remain for a certain period at rest; therefore, the centre line of that portion of the cam which is intended to keep the lever at rest, must evidently be a portion of a circle described from the centre C, and marked IX to s. The opposite face of the cam s a'' is set out in precisely the same manner as the portion a IX, but it does not follow that it has the same form, because the elements may be different. The portion a a' being a period of rest is likewise concentric to the centre C. From this centre line the half diameter of the roller or stud to be used on the follower of the cam is set off on both sides, so as to mark out a broad path having its two boundaries equi-distant at all points from the centre line a r r' a''. Within this path the roller travels in the same way as the pin in the grooved plate already described. A roller is used simply to diminish friction, and to prevent the abrasion and consequent change of form of the curved path.

In this machine all the cams are double; that is, the truck or roller attached to each of the levers is controlled in its motion by two surfaces, and not, as is often the case, by one surface, against which it is pressed by a spring. This latter method is objectionable on account of its absorbing a great amount of power; for unless the spring be strong enough to keep the truck in close contact, it is apt to fly off and produce shocks to the machinery, especially if the

steam engine or driving power should happen to be slightly accelerated in speed.

Each cam is formed by projection on a circular disc, the cam chace being counterbalanced by a projecting counterweight, cast opposite to its centre of gravity.

Each lever is also constructed so as to be balanced when swung at its centre. In the case of the two levers 4 and 5 of the plunger 6, Fig. 884, their construction only admits of their being balanced by the counterweights 4″, 4‴.

The principle of the cam being clearly understood, we next proceed to describe the various parts of the folding machine in the order of their work.

The functions of this machine are, to fold envelopes previously cut into the proper shape, and to secure the folds thus made by means of gum. The machine is fed with blank envelopes by a boy, at the rate of about one per second, this being the rate at which the principal cam revolves. The seal stamp is embossed on each blank, and the gum immediately under the seal is applied before the blanks are brought to the folding machine. This machine might be so arranged as to stamp the seal and feed itself; but in order to stamp efficiently, the parts must be made considerably stronger than they are in this machine, and it seldom happens that a sufficient number of envelopes are required from one seal to render such an adaptation economical. Moreover, every additional motion introduced must retard the progress of a machine; so that in this instance it is found more advantageous to engage the services of a separate machine. Then as regards feeding, a self-supplying apparatus would not in this case be of great advantage, because as some one must be present to superintend the machine, it is better that he be employed than remain idly looking on, for in such case his attention is apt to flag, and by allowing badly folded or broken envelopes to get into the machine much mischief may be done. Some idea of the precision with which this folding machine works may be gathered from the fact, that on an average there is not more than 1 envelope in 2,000 badly folded, and these generally arise from defects in the paper.

The blank envelopes, or *lozenges* as they are called, are cut out 250 at a time with great rapidity and precision, by means of an instrument identical in its action with a common gun-punch. E and F, Fig. 881, show two forms of lozenges, and may also be taken to represent the steel cutting edge of the punch. In the plain lozenge form E there is little or no waste of paper in the cutting out; but in the fancy envelopes (which are really less elegant in form than the plain lozenge) the waste is often considerable. Thus it will be evident, that there must be a greater waste in cutting out F, than in E. The waste paper is returned to the paper-maker to be made into pulp.

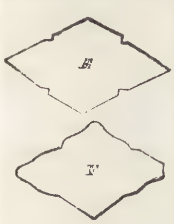


Fig. 881.

The blanks are next stamped with a seal at the embossing-press, [see EMBOSSING-PRESS,] and the seal flap is also gummed by hand. The lozenges thus prepared are then handed to the feeding lad, who places them one at a time on a small table T seen best in Figs. 882 and 883, in such a manner that the angles fall within the stops *g g g g*, which stops also form the bearings of the triangular folders 5′ 5′ 5′ 5′. As soon as the envelope is placed on this table, the compound box or plunger 5, Figs. 884, 886, 887, is brought down by the cam 3 upon the table T, and this plunger descending with the table into the recess formed by the four axes of the folders 5′, carries down the envelope and creases it in a rectangular form, the four triangular flaps standing up in a vertical direction. The ends of the plunger being moved by that side of the cam 3, shown by the dotted lines in Fig. 884, rise up so as to leave room for the two end folders 5′5′ to turn over, not simultaneously, but one slightly in advance of the other, Fig. 883, so that one of the end flaps of the envelope may overlay the other. These two triangular folders are moved by the cams 6 and 7, in the order of the numbering. But before the other two flaps are turned over, it is necessary that gum be applied in the exact spot, in order to cause three out of the four triangular flaps to adhere. The gumming apparatus is seen separately in Figs. 888 and 889, the gummer being marked 10 in the other figures. After the two end flaps are turned down, this gumming apparatus is brought forward by the cam 11, and prints on the two end flaps a line of gum imparted to it by an endless blanket. During the whole of these operations, the sides of the plunger 5, which had remained down so as to prevent the envelope from being disturbed, are now moved upwards by the cam 3, seen best in Fig. 884, and remain up until the commencement of the folding of another envelope; the two end folders remaining down to secure the envelope, and the gumming apparatus retreating. The two triangular side folders are now turned over by means of the two cams 8 and 9, one having a little the precedence of the other. The four folders then open simultaneously, leaving the envelope complete; but as the flaps of the envelope would, from the elasticity of the paper, be liable to spring open, there is a contrivance for keeping them pressed down; for which purpose, the apparatus which removes each envelope as soon as it is folded also places it in a pile immediately under the one last folded.

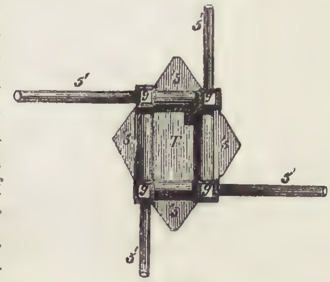


Fig. 882.

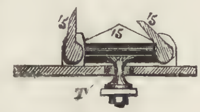


Fig. 883.

The taking off and piling apparatus consists of a slide 12, hinged at 12′, capable of rising and falling, and of a saddle 13′, carrying the fingers 13″, seen best in Figs. 886 and 887. This saddle moves in a hori

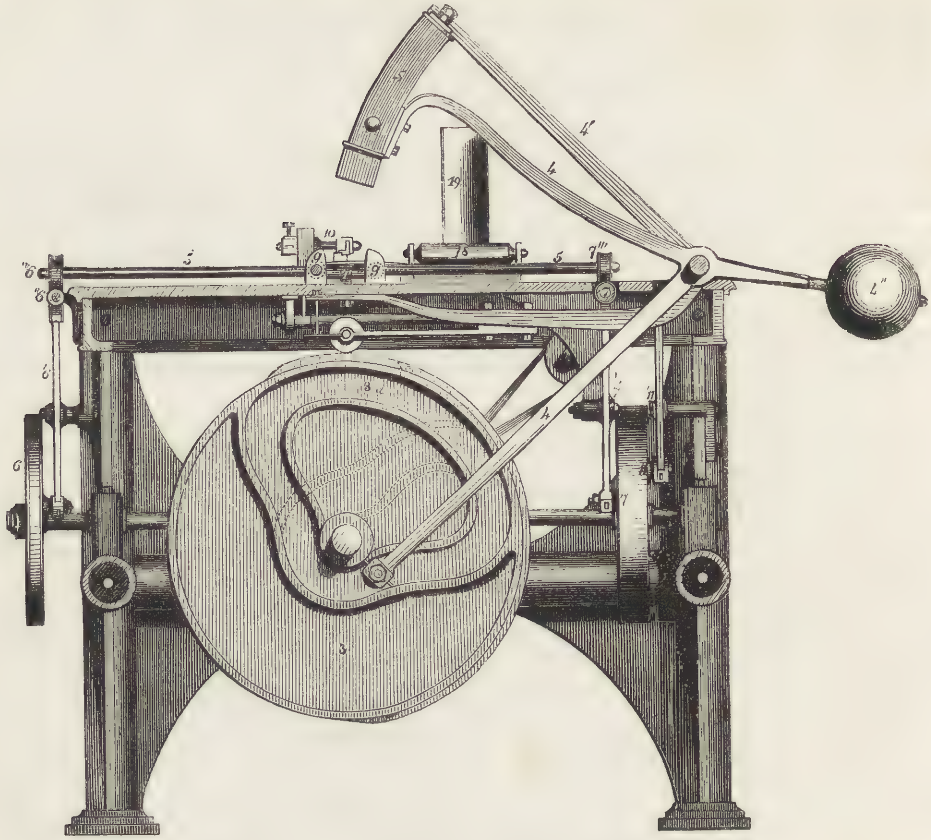


Fig. 884. SECTION OF FOLDING-MACHINE THROUGH THE LINE *a b* OF FIG. 887.

zontal direction on the slide 12. The points of the fingers move by a combination of these two motions, the vertical and the horizontal, in the line shown in Fig. 885, and in the direction of the arrows. After the envelope is folded, the fingers 13″ are brought down into the recess formed by the axes of the folders 5′, by means of the double cam 13, Fig. 887, one side of which is appropriated to the vertical motion of the slide, and the other to the horizontal motion of the saddle. When by these motions the fingers are brought into contact with the envelope, they are raised up, and at the same time the table T is made to rise with them, by means of a projection on the rim of the cam 3, Fig. 884, in such a manner as to keep the envelope firmly pressed against the fingers. The next motion of the fingers is the horizontal one; they are moved along the springing table 15, carrying the envelope with them, adhesion being promoted by tipping the points of the fingers with caoutchouc. As soon as the envelope reaches its destination under the pile, the slide is lifted by means of the cam 13, by which means the fingers are disengaged from the envelope, and they remain at rest until the next envelope is folded. The envelopes thus removed from the table are knocked over by means of a small beater 16, moved by a pin on the slide 12 on to an endless blanket 17, and pass under a small roller 18, which serves to compress the folds of the envelope more closely together. The envelopes then rise in a pile in the three sided trough 19, from which they are removed at intervals by an attendant.

Fig. 885.

On reference to Figs. 884, 886, 887, it will be seen that a series of racks 6″ 7″ 8″ 9″, serve to communicate motion from the levers 6′ 7′ 8′ 9′ to the wheels 6‴ 7‴ 8‴ 9‴, affixed to the folder axes 5 5 5 5. The object of this is to allow of the transmission of motion to the folding apparatus for envelopes of various sizes. The levers and racks retain their position, the folder axes being adjusted either at a greater or a less distance from the centre of the machine, in case a larger or a smaller envelope be required to be folded. Were it not for this provision, the cams and levers would have to be reconstructed for every variation in the size of the envelope, or, in other words, a new machine would be required for every size of envelope

The gumming apparatus, shown separately in Figs. 888 and 889, requires some further notice. The cam 11, Figs. 884 and 888, gives motion to the lever 11′, and this to the wheel 11″, and the axis to which it is affixed. The prolongation of this axis carries a lever *e*, and is hinged to a small frame *ff*, which carries the gummer 10. The curved lever *e′* is linked to the opposite side of the frame *ff*, and serves to retain it always horizontal to the plane of the table T, so that when the former moves forward on to the envelope, its action is very similar to that of the closing of a parallel ruler. This gummer 10

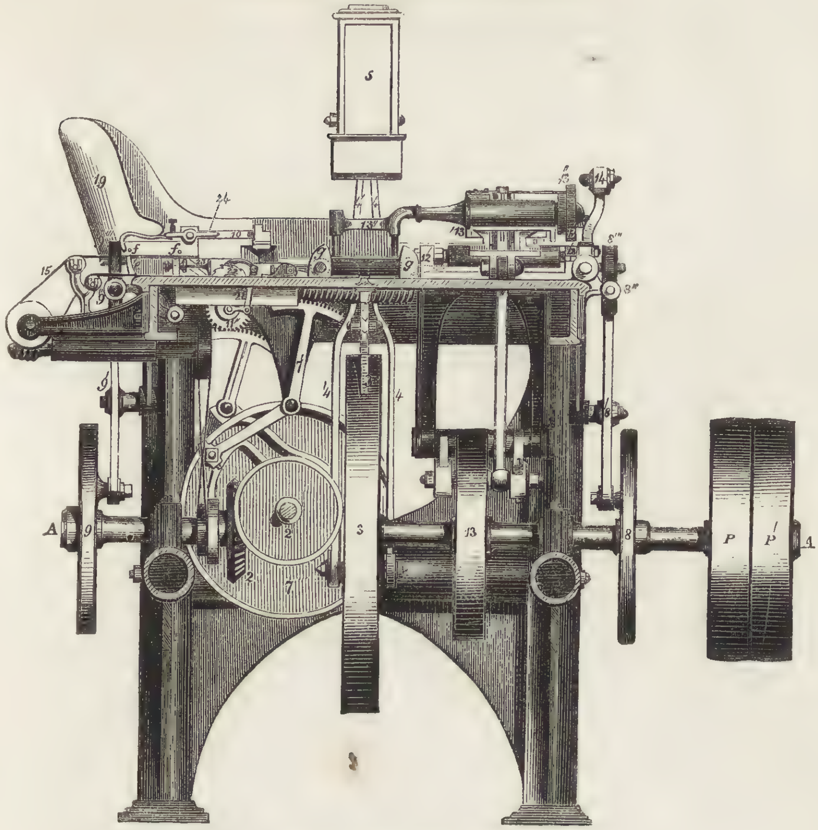


Fig. 886. SECTION THROUGH THE LINE *c d* OF FIG. 887.

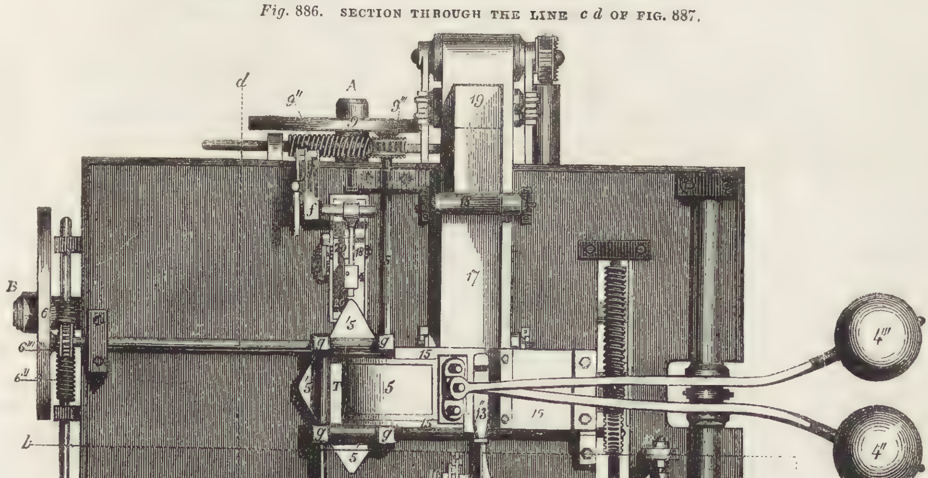


Fig. 887. PLAN OF THE UPPER PART OF THE MACHINE.

takes its gum from the endless blanket 20, Fig. 889, which moves in the trough 21, the quantity being regulated by the small doctor 23. The endless blanket is moved forward at each interval of motion of the gumming apparatus, by means of a paul or catch fixed to the

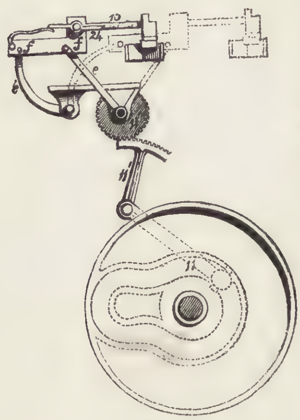


Fig. 888.

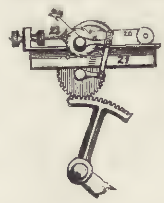


Fig. 889.

lever worked by the axis 11″, and working in a ratchet wheel 22, fixed to one of the rollers of the endless blanket. In Fig. 888, the two positions of the gummi g apparatus are shown.

As the principal cam revolves at the rate of about one revolution per second, it is necessary to feed the machine when in motion with a blank envelope at that rate. If the boy neglects to feed at the proper time, *i.e.* on the completion of one revolution, two things happen; the first and more serious one is, that the gummer would place gum on the small table T, so that the next blank envelope would be spoiled; secondly, the envelope which had been previously folded, and which by the arrangement of the taking off fingers is left projecting a little from the pile, would be knocked up in the heap, in consequence of which the succeeding envelope would enter the pile with so much difficulty, as to be crumpled up and spoiled, and it might also spoil several others. Both of these consequences are prevented by two stops, moved by the boy as soon as he fails to insert an envelope at the proper moment. The first stop being slid forward, touches a small lever 24, attached to the axis carrying the gummer 10, and lifts up this axis and the gummer as the frame is descending upon the table T; so that by this contrivance, as long as the stop remains in position, the gummer does not come in contact with the table: the second stop catches a projection 13‴, affixed to the axis of the fingers 13″, which are adjusted so as to turn in a small arc of a circle, so that as the saddle 13′ retreats along the slide 12, the fingers turn upwards and away from the projecting or *leading* envelope, as it is termed, which was previously folded. The slide in rising brings a projecting piece on the axis against a stop 14, which places the fingers in their usual position, and so long as the lad ceases to feed the machine (except, of course, when it is not at work) he leaves both these stops at rest; but as soon as he has fed the machine, he instantly removes them, and the operations proceed in the order previously described. By these simple contrivances, the waste of the machine is reduced to the small quantity already noticed. But it may be asked, Instead of these complicated provisions, why not adopt the apparently simpler course of stopping the machine, by shifting the strap from the fast pulley P, to the loose pulley P′? The answer is, that it is impossible either to stop or to start the machine instantly; for as the machine makes one whole revolution in a second, its several parts have a momentum due to that velocity, and could not be arrested in less than 3 or 4 seconds; but by the ingenious contrivances above described, no time is lost, except that required for the feeding of one envelope; and should the boy see a broken sheet of paper or find that two are stuck together, and require a brief instant to remedy the defect, he can thus secure it without stopping the machine.

This ingenious and highly interesting machine was patented on the 17th March, 1845, by Edwin Hill and Warren De la Rue. An apparatus for cutting out the blanks was also included in the same patent. Previous to this date, envelopes were cut out by means of chisels, the paper having been roughly cut to shape, and then held between two templates of the proper form. The envelopes were then folded by hand with the assistance of a common bone knife or folding-stick. A quick hand could on an average fold about 3,000 per day. Now the machine folds with a precision not attainable by hand, from 45 to 60 per minute; this is the average including all causes of stoppage; so that in a day of 10 hours, from 27,000 to 30,000 envelopes are completed, which when seen in a pile, appear as if they had all been cut to size by a knife.

In this machine, ecomony of space is as remarkable as rapidity of production and excellence of workmanship. This machine does the work of 10 skilful folders, and does not occupy more space than would be required by one folder. But it may be asked, is this really an advantage? Does not one of these machines deprive ten pairs of human hands of the means of earning bread? We have already examined this question in other articles of our Cyclopædia, and we again answer, No! If the 10 envelope folders who are superseded by 1 of these machines could absolutely do nothing else but fold envelopes, then they would suffer; but no one pretends that 10 busy, active and intelligent young women who have attained skill in this business, are incapable of quickly attaining skill in other occupations where activity and skill are required. Other occupations, it is true, may not be readily procured, and these 10 folders may for a time suffer from want of employment; but if our principle is true, that improved machinery increases employment among operatives, it is true in this case also, as the following details will show. The envelope-folding machine has made envelopes cheap, and as adhesive envelopes are convenient, the demand for them has surprisingly increased. Previous to the year 1839, envelopes were not used, because the Post Office charged double postage if one piece of paper were enclosed in another. The date of the Act for adopting postage reform, was 17th August, 1839, and

the date of the commencement of charge of postage by weight instead of by the number of enclosures, was the 5th December, 1839, when a fourpenny rate was adopted. On the 10th January, 1840, the penny postage rate commenced; envelopes were now introduced, but they were not much used. On the 6th May, 1840, stamps and stamped envelopes were introduced, and so convenient were the latter found, especially when made adhesive, that the use of them rapidly extended. Now we may get some idea of the demand for envelopes by the following table, showing the number of letters which have passed through the Post Office during the last 11 or 12 years. In 1839, before the introduction of the penny postage, the gross annual number of letters passing through the Post Office in the United Kingdom, was estimated at 76 millions.

In 1840,	it was	169	millions.
1841,	„	196½	„
1842,	„	208½	„
1843,	„	220½	„
1844,	„	242	„
1845,	„	271½	„
1846,	„	299½	„
1847,	„	322	„
1848,	„	329	„
1849,	„	337½	„
1850,	„	347	„

In 1841, about 50 per cent. of the correspondence of the United Kingdom passing through the Post Office, was in envelopes. In 1850, 300 out of every 336 letters were sent in envelopes: hence it may fairly be concluded at the present time, that ⅞ths of the letters posted are in envelopes, and that about ⅛th consist of folded sheets not in envelopes.

People are now so much in the habit of using envelopes, that the shortest written communication sent by hand is usually enclosed in one. In the year 1850, we find that 290 millions of envelopes were used in posted letters. Let us suppose, on a very moderate estimate, that a third of that number were used in letters which were not posted, but sent by hand or private conveyance; we thus have the enormous number of 386 millions of envelopes consumed in one year in this country alone, to say nothing of the quantities exported to the colonies, &c. To produce these envelopes by hand at their present price, would be simply impossible: to charge a higher price in order to remunerate the army of folders required to produce so vast a quantity, would be to destroy the envelope trade; for unless envelopes continue to be sold at an exceedingly cheap rate, the demand for them would decline far more rapidly than it originated. Now the effect of this increased demand for envelopes is to multiply labour. In the *first* place, the demand for paper is so great, that at the present time a scarcity of rags is being felt; in the *second* place, the tool-makers and the engineers are actively employed in supplying envelope machines, and the subsidiary apparatus, and keeping them all in repair; *thirdly*, new punches are being constantly made for stamping the crest or the initials of the consumer on his envelopes, or for embossing fancy patterns thereon; while the embossing-press is kept in constant activity. *Fourthly*, the demand for gum for adhesive envelopes is now so large, as to have originated a new branch of manufacture to supply it. [See GUM.] We might go on to point out the moral effects of the envelope machine; how, by increasing the facilities for letter writing, the intellectual occupations of the people are increased, their mutual sympathies kept alive, and the great cause of popular education encouraged; but we trust that enough has been said to show that the introduction of so active a producer as the envelope-folding machine, is not an industrial evil.

In the Great Exhibition, a second folding machine by M. Rémond is shown. It differs from the machine already described in some respects, which we may briefly notice. This machine is self-feeding, for which purpose a hollow arm moving backwards and forwards, is alternately exhausted and filled with air. In its exhausted state it arrives just over a pile of blank envelopes or lozenges, the top one of which clings to it by atmospheric pressure: the arm then moves on, becomes filled with air, and drops the blank upon a movable table. A dabber then falls down and presses the envelope against two gum troughs which contain a sponge and resemble the wick-holder of a lamp, they being so adjusted as to place the gum where it is wanted. A rectangular frame or plunger next forces the paper into a rectangular opening. Each of the four corners is then inclined inwards by a puff of condensed air which issues from a slit near it. The hollow plunger then falls down a second time, and completes the fold by three internal projections concealed from view. The envelopes are removed singly by hand, placed in a pile, and then slightly pressed. This machine is not nearly so certain in its action as that previously described.

EPROUVETTE. See GUNPOWDER.

EPSOM SALTS. See MAGNESIA.

EQUILIBRIUM (from *æqua libra*, equal weight). A body is said to be in equilibrium when the forces which act upon it mutually counterbalance each other, or when they are counterbalanced by some passive force or resistance. Thus a body suspended from the end of a thread is in equilibrium, because the attraction of gravitation, which would cause it to fall, is counterbalanced by the resistance of the thread, and by that of the point of suspension. A body may be in equilibrium without any apparent resistance. Thus a fish may be in equilibrium in water, and a balloon in air; but the weight which would cause the fish to sink or the balloon to fall, is exactly counterbalanced by other forces. We may, however, regard all bodies which appear to us to be at rest, as being actually in a state of equilibrium, or equally balanced between or among forces which destroy each other. The conditions of equilibrium are determined by the science of STATICS, (στατὸς, standing still,) as regards solids; and by HYDROSTATICS, (ὕδωρ, water, and στατος,) as regards fluids.[1]

EQUIVALENTS. See ATOMIC THEORY.

(1) See Tomlinson's Mechanics, published in Weale's Rudimentary Series, second Edition, 1851.

ERMINE. See FUR.

ESCAPEMENT. See HOROLOGY.

ESSENTIAL OILS. The *essential* or *volatile* oils may be regarded as the odorous principles of vegetables, and the term is generally applied to these products, as obtained by distilling the plant with water; in some cases the oil is thus derived from the fresh or salted plant, as from roses and orange flowers; in others, from the dried plant; and sometimes it may be pressed out of the cellular structure containing it, as in orange and lemon peel. These oils are frequently obtained from every part of the plant, but there are generally peculiarities in the oil derived from different parts of the same plant; thus, with regard to the orange-tree, the leaves, flowers, and fruit, each yield a distinct oil. The boiling-points of almost all these oils are above that of water, but their vapours are carried over with steam at 212°, and condensed with it in the refrigerator; a portion of the oil is, however, always retained in solution in the water, constituting what are called *medicated* and *perfumed waters*, while the remainder either floats upon the surface or sinks to the bottom, according as it is less or more dense than distilled water. The greater number of these oils are lighter than water, and in such cases, the distilled product is received into a vessel called a *Florentine receiver*, Fig. 890. It is conical in form, and at the side is a spout *b c* communicating with the bottom, the orifice *c* of the spout being much lower than the mouth *a* of the receiver. The distilled product being poured in this vessel, the oil B separates from the water A, and occupies the upper part of the vessel. The water as it rises above the bend of the spout flows off at *c*, while the essential oil may be from time to time removed by means of a pipette. In some cases the oil and water are separated from each other by pouring the contents of the recipient into a funnel, the tube of which is closed by the finger, and, when the oil has collected upon the surface, the water is suffered to run from beneath it, and the oil is transferred into a bottle. When the oil is heavier than water, these operations are of course inverted. Instead of a common funnel, the *separator*, shown in Fig. 891, may be conveniently employed, as the oil may be retained in it, and at the same time preserved from contact of air. The distilled water, being in these cases already saturated with the oil, should be retained for a repetition of the distillation. The produce of oil is sometimes stated to be increased by adding salt to the water in the still, so as to elevate its boiling point. When, as in the case of oranges, lemons, and similar fruits, the oil is expressed instead of distilled, the yellow part of the rind is rasped off and pressed in hair-cloth bags; the expressed juice separates, on standing, into two distinct portions, the inferior of which is aqueous, and the superior oily. The oil thus obtained is generally more fragrant than when heat has been resorted to, but it is at the same time less pure; and, although it gradually clarifies itself, by depositing the substances held in mechanical suspension, it retains colouring and other matters in permanent solution, so that when dropped upon paper it leaves a stain, and does not produce a clear alcoholic solution. There are some of these oils which are produced in such small quantities, or which are so delicate and evanescent, as not to admit of collection by either of the preceding methods, such as the fragrancy of the flowers of the jasmine, the violet, the tuberose, the lime-tree, the narcissus, and some others. To obtain these, the fresh flowers are stratified with layers of cotton imbued with some inodorous fixed oil; this gradually absorbs the volatile oil or perfume of the flower, and when saturated with it, the cotton is digested in alcohol, which abstracts the essential from the fixed oil, and an odoriferous *essence* is obtained. Sometimes the cotton is distilled with water or with alcohol, and the oil separated by that process; it is, however, generally too delicate to admit of such treatment without great deterioration, or even entire destruction.

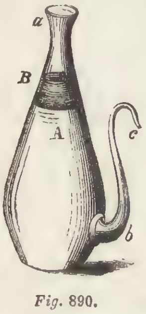


Fig. 890.


Fig. 891.

The essential oils are applied to many useful purposes; the cheapest and most abundant are used in the manufacture of paints and varnishes, and are occasionally burned in lamps; others are employed in pharmacy and medicine, and are generally powerful and diffusible stimulants; others, and especially such as possess agreeable odours, are used for the various purposes of perfumery. In general, these oils are ready formed in the plants whence they are derived, but in some cases they are no doubt generated by the action of water upon peculiar principles existing in the vegetable. Hence, also, some plants which are naturally inodorous, yield a strongly scented volatile oil after they have been subjected to fermentation, as in the case of the *lesser centaury* (Centaurium minus). There are also a few instances in which essential oils have been artificially produced.

When fresh and pure, the essential oils are mostly colourless, or nearly so; but they are generally of various tints of yellow or brown, or soon become so under the influence of air; some few of them are green and blue, and several of them, even after having acquired colour, lose it under the continuous influence of light. Their odours more or less resemble those of the fresh plants whence they are derived, but are less agreeable, partly in consequence of concentration, for they become more pleasant when diluted by, or diffused through a large bulk of air, or when attenuated by solution in some inodorous vehicle.

Liebig has observed that the odour of these oils is greatly influenced by their chemical relations to air and water; that they all absorb oxygen; and that those which do so most rapidly, are most odorous.

If non-oxygenized oils (hydrocarbons) be distilled off quicklime, either *in vacuo* or in a stream of carbonic acid, the product is so far inodorous, that it is difficult, under these circumstances, to distinguish oil of lemons, of juniper, and of turpentine, from each other; but after exposure to air, especially if spread upon a piece of paper, their natural characteristic odours return, and they at the same time become viscid and resinous, so that it would appear as if the odour was the result of the act of oxidizement, as is the case with metallic arsenic.

They are almost all possessed of strong, aromatic, and often extremely pungent and burning flavours, and many of them are poisonous. They have not the greasy feel of the fat oils, but, on the contrary, are rather rough upon the cuticle, and cause a cork moistened by them to squeak when twisted into a phial. They are inflammable, and burn with a bright, but often very smoky flame.

The specific gravity of the essential oil fluctuates between the extremes of 0.846 and 1.097. The greater number of them are lighter than water, as shown in the following table of their average specific gravities; but the results can only be considered as approximate, for the densities appear to vary with the mode of distillation and the period of that process at which they are collected, the first portions which pass over being often less dense than the last. They are also influenced by the condition of the plant, the period at which it is cropped, the age of the oil, and its greater or less exposure to air; so that the same kind of oil, produced in England, and elsewhere, often varies considerably. Thus Proust found camphor in the oils of some of the *labiatæ* of Spain, while there was none in those of France.

Specific Gravities of the Essential Oils.

Oil of aniseed, (English)	0.9868
,, ,, (Foreign)	0.9903
,, bergamot	0.850
,, cajaputi	0.9263
,, caraway	0.9310 to 0.94
,, cassia	1.071
,, chamomile (English; from flowers only)	0.9083
,, ,, (Foreign)	0.9289
,, cinnamon	1.036
,, cloves	1.034 to 1.052
,, copaiva	0.878
,, cubebs	0.929
,, cumin	0.860
,, dill	0.994
,, elemi	0.849
,, fennel	0.997
,, juniper (English)	0.8688
,, ,, (Foreign)	0.8834 to 0.9110
,, lavender (English, from flowers only)	0.8960
,, ,, (English, from the whole herb)	0.9206
,, lemon peel	0.8569
,, marjoram	0.9090
,, nutmegs	0.9480
,, orange peel	0.8880
,, pennyroyal	0.9390 to 0.9780
,, pepper	0.8640
,, peppermint (English)	0.9070
,, pimenta	1.021
,, rosemary	0.9118
,, rue	0.8670
,, sassafras	1.094
,, spearmint	0.9394
,, spike lavender	0.9360
,, turpentine	0.870

The greater number of the volatile oils appear to be mixtures of two, and sometimes of three different products; one of which is a *hydrocarbon*, and the other an *oxyhydrocarbon;* and in many cases the latter, when isolated, assumes a concrete form, constituting a species of *camphor*. Berzelius applies the term *stearoptene* and *elaioptene* to these solid and fluid products; (from *στέαρ*, fat, or *ἔλαιον*, oil, and *πτηνὸς*, volatile;) and they often admit of separation by the application of cold, which causes the camphor to solidify; or by distillation, when the portion of the oil which is destitute of oxygen passes over at a lower temperature than that which contains oxygen: but when these mixed oils are thus distilled, their separation is never perfect, the more volatile hydrocarbon always carrying over with it a portion of the less volatile oxyhydrocarbon; so that other methods are resorted to, entirely to deprive the former of oxygen, amongst which, the action of fused caustic potassa is one of the most efficient, for by it the whole of the oxygen (and part of the carbon) is abstracted in the form of carbonic acid. This variable composition of the essential oils explains the inequality of their boiling points; but frequently the cause of the rise of the thermometer during the progress of distillation, depends upon a progressive decomposition of the oil, in which case more or less gas is generally evolved. Although nearly all these oils are, as just stated, constituted either of carbon and hydrogen, or of carbon, hydrogen, and oxygen, there are a few which contain sulphur and nitrogen, but these are of a very peculiar character.

The essential oils being dissolved in small quantity, by water, to which they communicate taste and odour, the London Pharmacopœia directs the extemporaneous preparation of several of these waters, by adding the oil (subdivided by trituration with a little carbonate of magnesia) to simple distilled water, instead of distilling the water off the herb itself: a little alcohol is also directed to be added to the water, with a view of preserving it from change; but Mr. Warington has shown, that alcohol has the opposite effect, and that distilled waters which keep well without such addition, are liable to acetification with it. Some of these oils apparently enter into chemical combination with definite proportions of water to constitute crystallizable compounds, or camphors. They dissolve abundantly in absolute alcohol, and in ether.

Exposed to the influence of oxygen, or air, the volatile oils undergo two distinct series of changes; some of them seem directly to combine with oxygen to form crystallizable, and, in many cases, acid compounds; but in other cases the action of air changes the oil into a resinous substance, a portion of its hydrogen being probably converted into water, so as to leave excess of carbon in the residue. The action of chlorine upon many of these oils is attended by the immediate production of hydrochloric acid, and compounds of chlorine and of hydrochloric acid, with the remaining elements of the oil, are formed. The same happens with iodine and with bromine; and in some cases the decomposition of the oil thus effected

is so intense as to give rise to inflammation. The action of acids, and other agents, varies considerably with the nature of the oil; the action of nitric acid is also for the most part intense, and frequently attended by the formation of a resinoid product.

Amongst the essential oils which are destitute of oxygen, (the hydrocarbons of the series,) there is a remarkable identity of composition; they contain between 88 and 89 *per cent.* of carbon, and between 11 and 12 *per cent.* of hydrogen, proportions which are expressed by the formula C_5H_4; so that their varieties may be generally regarded as isomeric or polymeric modifications of a hydrocarbon so constituted; being namely, C_5H_4, or $C_{10}H_8$, or $C_{20}H_{16}$, or $C_{40}H_{32}$, points which are best determined by the respective densities of their vapours, it being obvious that in respect to the equivalent, or atomic weight of the compound, as deduced from its combinations, it may be represented as C_5H_4 or $2\,(C_5H_4)$, $3\,(C_5H_4)$, $4\,(C_5H_4)$, &c. In some cases these isomeric modifications only admit of distinction by their action upon polarized light, some of them rotating the ray to the *right*, others to the *left*, and others transmitting it uninfluenced, showing that although there is identity of composition, of atomic weight, and even of density of vapour, there is nevertheless a difference in their molecular constitutions.

In consequence of the high price of many of these oils, they are variously adulterated, sometimes with alcohol and with fixed oils, and sometimes with the cheaper essential oils. When alcohol is used, it may generally be separated by agitating the adulterated oil with water, or with a saturated solution of common salt, and its quantity appreciated by the diminution of bulk which the oil so treated sustains: this falsification is also indicated by a slight increase of temperature when the oils are mixed with water, and which is not observed when they are pure. Alcohol may also be abstracted from an essential oil by means of fused chloride of calcium. The volatile oils, when pure, dissolve perfectly in all proportions in the fixed oils, without interfering with their transparency; but not so when the former are adulterated with alcohol: in that case, a few drops of the adulterated oil added to a perfectly transparent fixed oil, produces more or less turbidness. The admixture of a *fixed oil* is ascertained by the greasy stain which remains when a drop of the oil is evaporated before the fire from a piece of bibulous paper; but some of the genuine essential oils, especially such as are old, or have been exposed to air, often under these circumstances leave a stain, which, however, is rather resinous than greasy. When an essential oil thus adulterated is rubbed between the finger and thumb, it generally has more or less of a distinct greasy feel; or if distilled with water, the fixed oil remains behind; if mixed with about thrice its bulk of alcohol, of sp. gr. 0.84, the fixed oil is also separated.

The adulteration of a *high-priced* with a cheaper essential oil, is more difficult of detection, and requires for its discovery a practical acquaintance with the odour, flavour, and other distinctive characters of the genuine oil, which can only be attained by experience. When oils are falsified with oil of turpentine, its characteristic odour is often covered, till the adulterated oil is dissolved in a little alcohol, and the solution mixed with water, when both the odour and flavour of the turpentine become manifest. The refractive indices of the adulterated oils generally differ from those of the genuine article, and Dr. Wollaston suggested a form of instrument for their determination, which has been improved by Mr. Cooper: it is often useful, but the refractive power of the genuine oil varies too much to render it satisfactorily available.[1]

ETCHING. See Engraving.

ETHER. The action of sulphuric acid upon alcohol aided by a moderate heat, leads to the production of a remarkable volatile liquid called *sulphuric ether*, or simply and more correctly *ether*, because it contains neither sulphur nor sulphuric acid. It was first described by Valerius Cordus, in 1540, who published precise directions for making it. After this it sunk into oblivion until 1729, when Frobenius, in a paper in the Philosophical Transactions, described its singular properties. A note at the end of this paper by Godfrey Hankwitz, Boyle's operator, states that experiments had been made upon it both by Boyle and by Newton. In modern chemistry the process of etherification has been minutely studied.

Ether was obtained until recently by simply distilling a mixture of sulphuric acid and alcohol. The following are the directions for the process:—"Mix with 16 ounces of sulphuric acid an equal weight of rectified spirit, and distil about 10 fluid ounces; add 8 ounces of spirit to the residuum in the retort, and distil about 9 fluid ounces; or continue the operation until the contents of the retort begin to rise, or the product becomes considerably sulphurous; mix the two products, or if the mixture consist of a light and a heavy fluid, separate them: add potash to the lighter as long as it appears to be dissolved: separate the ether from the solution of potash, and distil about $\frac{9}{10}$ths of it to be preserved as *ether sulphuricus*, the sp. gr. of which ought to be at most .750."[2]

When this process is conducted on a small scale, glass vessels may be used, but on a large scale, a leaden still should be employed. At Apothecaries' Hall, the ether-apparatus consists of a leaden still, which is heated by means of high-pressure steam carried through it in a spiral pipe. A tube enters the upper part of the still for the purpose of introducing the alcohol. The still-head is of pewter, and is connected by about 6 feet of tin pipe with a capacious condensing apparatus cooled by a current of water. The receivers are of pewter with glass lids, and furnished with a side tube to connect them with the delivering end of the condensing pipe. From the highly inflammable nature of ether and its vapour, great care must be taken to remove the operation from the vicinity of fire; hence the use of heating by steam.

(1) Abridged from Professor Brande's "Manual of Chemistry," 1848.

(2) Phillips, "Experimental Examination of the London Pharmacopœia."

The old method of preparing ether is both wasteful and inelegant. By the new method, alcohol is allowed to drop into the hot acid, in which case the form of apparatus shown in Fig. 892, may be used for preparing ether upon a large or a small scale. A is the

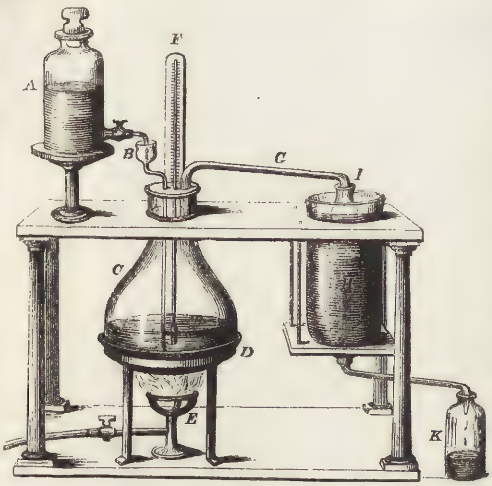


Fig. 892. ETHER DISTILLATORY APPARATUS.

vessel for holding alcohol: it has a grooved stopper, so that when the stop-cock is turned more or less, the alcohol may drop with the required degree of rapidity into the funnel B, the tube of which is elongated, and terminates by a small aperture near the bottom of the flask C, which is placed in a copper sand-bath D, supported on a ring, and heated by the gas-burner E. The temperature of the mixture in the flask can be noted by means of the thermometer F. A wide glass tube G, conveys the vapours from the flask to the condenser H, which is surrounded by cold water in the vessel I, and delivers its contents into the receiver K.

A mixture of 8 parts by weight of concentrated sulphuric acid and 5 parts of rectified spirit of wine of sp. gr. 0.834, is introduced into the flask and heated up to 300°, when it boils. Alcohol is then allowed to drop in through the long funnel, and by regulating the quantity admitted and by turning the gas more or less on, the temperature of 300° is maintained as steadily as possible, and the liquor in the flask kept in brisk ebullition. In this way all the alcohol that is admitted may be converted into vapour of ether and of water, and the mixed vapours passing through G are condensed in H, while ether and water fall into K, and arrange themselves into separate layers, the water being at the bottom.

The bulk of the liquor in the flask will be tolerably constant if the operation be successful. The great point is to keep up the temperature so as to produce rapid ebullition. Etherification takes place between 260° and 310°, and if too much alcohol or too weak an acid be used, so as to reduce the boiling point below 260°, the alcohol distils over almost unchanged; if, on the other hand, too much acid be employed, the temperature rises to 320° or thereabouts, and olefiant gas and other products are generated.

The theory of the formation of ether will be understood from the following details. When strong rectified spirit of wine is mixed with an equal weight of concentrated sulphuric acid, heated to the boiling point and left to cool, an acid known as the *sulphovinic* is formed. If the cold mixture be diluted with water and neutralized with chalk, a large quantity of sulphate of lime is formed. On filtering and pressing the mass through a cloth, a clear solution is obtained, which must be evaporated to a small bulk, filtered, and left to crystallize. Beautiful colourless transparent crystals of sulphovinate of lime are thus formed. By substituting carbonate of baryta for chalk in the above process, a similar salt is produced, from which the hydrated sulphovinic acid (C_4H_5O, $2\,SO_3+HO$) may be procured by precipitating the base by dilute sulphuric acid, and evaporating the filtered solution *in vacuo*. It is a sour syrupy liquid easily decomposed by heat; and it is upon the formation and subsequent decomposition of this acid, that the formation of ether is supposed to be due.

When the mixture of alcohol and sulphuric acid, in the process for making ether, is diluted so far as to boil at 260° or under, the sulphovinic acid that is formed is resolved into sulphuric acid (SO_3), which remains behind, and alcohol (C_4H_5O, HO) with a mere trace of ether (C_4H_5O), which pass over in vapour as already noticed. But when the mixture has its boiling point between 260° and 310°, the sulphovinic acid is resolved into hydrated sulphuric acid ($SO_3\,HO$), which remains behind, and ether (C_4H_5O) accompanied by only very small quantities of alcohol, which pass over in vapour.

By the old process of making ether from a mixture of equal parts alcohol and sulphuric acid, the conditions as to temperature could not be complied with. At first the temperature was too low to yield much ether, and towards the end, long before the sulphovinic acid had been decomposed, it was too high, and olefiant gas and its accompanying products were produced. But by the *continuous process, i. e.* by allowing alcohol to trickle in, the alcohol combines with the sulphuric acid as fast as it is liberated, and sulphovinic acid is reproduced as fast as it is decomposed. In this way a small quantity of sulphuric acid is made to etherify an almost indefinite quantity of spirit, and it might be indefinite were it not that the sulphuric acid slowly volatilizes, partly in the state of oil of wine, and it is this loss of acid which is the only limit to the duration of the process. The ether of commerce usually contains alcohol and sometimes a little water, and if long prepared it may also be slightly acid. Perfectly pure ether is prepared by shaking the ether of commerce in a close vessel with about twice its bulk of water; by repose it will separate and occupy the surface: it is then poured off, and a sufficient quantity of well-burnt lime added to it, by which means the water imbibed during the *washing* is removed. The mixture of ether and lime is next distilled; the first third that distils over is pure ether, free from alcohol and water.

Ether is a highly volatile, transparent, colourless,

limpid liquid, of a penetrating, and to most persons agreeable odour, and a pungent and sweetish taste: it is very exhilarating, and produces a remarkable species of intoxication, when its vapour mixed with air is respired. By proper management, a continuous insensibility to pain may be kept up, by causing the patient to inhale this vapour. Hence its use in surgical operations; but in many respects, chloroform is preferable for this purpose. [See CHLOROFORM.] Ether is neither acid nor alkaline: it has a high refractive power, and is a nonconductor of electricity. It is slightly soluble in water, 9 parts of which take up 1 of ether. Washed ether retains about a tenth part of water, or according to Liebig, 36 parts of pure ether dissolve 1 part of water. The specific gravity of ether at 68° is 0.713. It boils at mean pressure at 96.5°; but the boiling point is influenced by the nature and state of the vessel in which the experiment is made. [See EBULLITION.] Ether is so exceedingly volatile that it cannot be poured from one vessel into another without loss; hence it is dangerous to take the stopple out of a bottle of ether near a lighted candle. Vapour of ether is much denser than atmospheric air, in the ratio of 2.58 to 1. If a few drops of ether be moved round in a deep wine or test glass, so as to wet the sides, the glass will soon be filled with vapour, which vapour can be poured like water or carbonic acid into another glass, from which it will displace the air. A lighted match applied to the glasses will detect the presence of the vapour in the second glass, and its disappearance from the first. A drop of ether on the hand produces cold, in consequence of the rapid evaporation. Professor Brande has given an elegant experiment to illustrate the production of cold in this way. Let a few drops of ether fall upon a drop of water, so as to cover it; then blow upon it with a blow-pipe, and the water will soon freeze into a lump of ice. Ether has not been frozen, even when exposed to a temperature of 166° below zero. Ether should be preserved in well stoppled bottles, or in sealed tubes, in a dark place. Exposed to air and light, a little acetic acid is formed in it, and it becomes acid to tests. When ignited, ether burns away with a bright and slightly sooty flame, leaving no residue, and producing carbonic acid and water. Mixed with about ten volumes of oxygen, it explodes violently by an electric spark. When vapour of ether is passed over red hot platinum wire formic and acetic acids are produced.

Alcohol and ether mix in all proportions. Ether dissolves, more or less, iodine, bromine, sulphur ($\frac{1}{100}$th), phosphorus ($\frac{2}{100}$ths), the fixed and volatile oils, many of the resins, caoutchouc, various forms of extractive, the alkaloids, and some other vegetable principles. Sulphur and phosphorus may be obtained in small crystals by evaporating the ethereal solutions.

Ether has been found by analysis to contain C_4H_5O, so that it differs from alcohol, $C_4H_6O_2$, by HO, the elements of water. Alcohol also furnishes a number of *compound ethers*, as they are called, by the action upon it of different substances; and the constitution of these compound ethers admits of comparison with ordinary salts by putting in the place of the metal a hypothetical salt-basyle, named *ethyle*, containing C_4H_5. This substance may be supposed to form haloid-salts by combining directly with chlorine, iodine, bromine, &c.; and the *oxide of ethyle*, or common ether, taking the place of the basic metallic oxides, may combine with oxygen-acids and form salts. Although ethyle has not yet been isolated, and is therefore a purely imaginary compound, yet its adoption has been found to simplify in a happy manner the theory of the ethers. The following is a table of ethyle compounds:—

Ethyle	C_4H_5
Oxide of ethyle, or *ether*	C_4H_5O
Hydrate of the oxide of ethyle, or *alcohol*	C_4H_5O, HO
Chloride of ethyle	C_4H_5, Cl
Bromide of ethyle	C_4H_5, Br
Iodide of ethyle	C_4H_5, I
Cyanide of ethyle	C_4H_5, C_2N
Nitrate of the oxide of ethyle	C_4H_5O, NO_5
Hyponitrite of oxide of ethyle	C_4H_5O, NO_3
Oxalate of oxide of ethyle	C_4H_5O, C_2O_3

EUDIOMETER, an instrument invented by Priestley, and since produced in a variety of forms by different chemists, for ascertaining the composition of atmospheric air under various circumstances. The use of the eudiometer, termed *eudiometry*, has since been extended to all gaseous mixtures, but especially to the determination of the quantity of oxygen which they contain when resulting from the operations of chemical analysis.

The principle of the eudiometer, so far as it relates to atmospheric air and oxygen gas, is to expose them to the action of some substance, solid, fluid, or gaseous, which will combine chemically with the oxygen, and leave the gas or gases with which it is mixed unacted upon. For example, the eudiometer of Seguin is a glass tube 8 inches long, and about 1 inch in diameter, and open at one end; it is filled with and inverted in mercury: a small piece of phosphorus is then put under the open end of the tube, and it rises to the top of the mercury, where it is melted by holding a hot iron near it. A measured portion of the gas to be examined is then passed into the tube; the phosphorus inflames on each addition of the gas, and the mercury rises, owing to the condensation of the oxygen. The quantity of the residual gas is determined by transferring it into a graduated tube, and the difference between the quantity submitted to experiment and that which remains, indicates the amount of oxygen absorbed. Berthollet, in his eudiometer, employed a similar method, only instead of igniting the phosphorus, he allowed it to combine with the oxygen by slow combustion. In the course of six or eight hours the whole of the oxygen disappears, and its quantity is indicated by the rise of the mercury or the water in the tube; while the amount of nitrogen is shown by the quantity of gas left in the tube.

Volta determined the quantity of oxygen in a gaseous mixture, by mixing therewith a known volume of hydrogen gas, and then firing it by means of an electric spark. As it is known that every two volumes of hydrogen combine with and condense one volume of oxygen, the contraction of volume in the mixture will

be due to the oxygen. One form of Volta's eudiometer is shown in Fig. 893. It consists of a very thick, graduated glass tube, from 18 to 24 inches long, and about 4 lines internal diameter: it is open at one end, and closed at the other. Near the top A, the tube is perforated, and platinum wires are fixed in the holes, the ends within the tube being at such a distance apart as to allow the passage of the electric spark between them: on the outside the wires are furnished with hooks or knobs. Near the opening B the tube is perforated at the side, and furnished with a glass cock, which is closed after filling the tube with the gas to be examined. This prevents any loss of gas in consequence of the great expansion which precedes the condensation of the gases. When the spark has been passed, the cock is turned under water, or mercury, and the fluid rises in the tube: the condensation is then noted by bringing the fluid within and without the tube to the same level.

Fig. 893.

Another modification of Volta's eudiometer, contrived by Dr. Ure, is shown in Fig. 894. It consists of a glass syphon, the internal diameter of which is from $\frac{2}{10}$ to $\frac{4}{10}$ of an inch: its limbs are each from 6 to 9 inches in length, and about $\frac{1}{2}$ an inch asunder. The open extremity is slightly funnel-shaped; the other extremity is hermetically sealed, and is furnished with two platinum wires, made tight by fusing the glass round them. The instrument having been graduated, is filled with water or mercury, and the gas transferred into it: then being held upright, part of the fluid in the open leg is displaced by inserting a glass rod. The open leg ought to contain at least two inches of air between the thumb and the mercury, in order to serve as a sort of recoil spring. The open leg being grasped by the hand, the thumb is to be placed lightly over the aperture so as to close it, and at the same time to touch one of the wires: a spark taken from the conductor of an electric machine, or from the knob of an electrophorus, to the other wire, passes through the gas, ignites it, and is conducted off by the thumb. The gas in expanding depresses the fluid beneath it, and the air below the thumb acts as a spring to restrain the violence of the explosion. When the explosion is over, the subsequent condensation will be felt by the thumb being pressed down to the orifice by the atmospheric pressure: on gently sliding the thumb on one side, and admitting the air, the column of mercury in the sealed leg will rise more or less above that in the other: mercury is then to be poured in till the equilibrium is restored, and the resulting volume of gas is then read off.

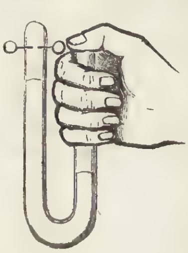


Fig. 894.

An elaborate form of eudiometer has been contrived by M. Regnault, a description of which will be found in the fourth volume of that gentleman's excellent *Cours de Chimie*, Paris, 1850.

EVAPORATION is the process by which a liquid gradually disappears or diminishes in bulk by the formation of vapour at its surface. In the process of EBULLITION, vapour forms at every point of the liquid mass. It is a matter of daily experience, that water evaporates into the atmosphere at all temperatures, however low. The water deposited by a shower of rain soon dries up, even in winter, and in the dry warm weather of summer ponds disappear, and brooks and running waters diminish in volume. The process of spontaneous evaporation applies also to other liquids. Faraday has shown that vapour rises from mercury at common temperatures, at least from 60° upwards. He placed some mercury in the bottom of a glass bottle, and attached a piece of gold leaf to the bottom of the stopple: in the course of a few weeks the gold became white by amalgamating with the vapour which ascended from the mercury. Some solids also, such as camphor, disappear by the process of spontaneous evaporation.

It was formerly supposed that evaporation was due to an affinity between the particles of air and the particles of the liquid exposed to it, whereby a combination was formed, and a constant absorption of liquids by the air took place. Dr. Dalton was the first to establish the true philosophy of the process: by a series of beautiful and simple experiments he was led to the conclusion that the vapour of water, and probably of most other liquids, exists at all temperatures in the atmosphere, and is capable of bearing any known degree of cold without a total condensation, and that the vapour so existing is one and the same thing as *steam*, or vapour of 212° or upwards. The idea, therefore, that vapour cannot exist in the open atmosphere at a lower temperature than 212°, unless chemically combined therewith, he considered as erroneous: it has taken its rise from a supposition that *air* pressing upon vapour condenses the vapour equally with *vapour* pressing upon vapour; a supposition we have no right to assume, and which he apprehended will plainly appear to be contradictory to reason, and unwarranted by facts; for when a particle of vapour exists between two particles of air, let their equal and opposite pressures upon it be what they may, they cannot bring it nearer to another particle of vapour, without which no condensation can take place, all other circumstances being the same; and it has never been proved that the vapour in a receiver from which the air has been exhausted, is precipitated upon the admission of perfectly dry air. Hence, then, we conclude, till the contrary can be proved, that the condensation of vapour, exposed to the common air, does not in any manner depend upon the pressure of the air.

To clear up this question Dalton determined by experiment, *first*, the expansive force of dry air for each degree of temperature between 32° and 212°. He also found that 1,000 cubic inches of air at 32° expanded into 1,376 on being heated to 212°.[1] He also ascertained, *secondly*, the force of pure steam in contact with

(1) Gay Lussac's result, obtained soon after Dalton's, was 1,375

water for each degree throughout the same range; and *thirdly*, he found at what rate dry air expanded when put in contact with water, and heated through the various degrees of that range. The result was, that at any particular temperature the expansive force of dry air in the first case, added to the force of vapour in the second, was exactly equal to their joint expansive force in the third. Hence there was either no chemical combination between air and vapour, or, if it existed, it was quite inert. When other gases were substituted for air, the vapour gave the same results, and similar results were obtained when other vapours were treated as steam. The quantity of vapour in a given space was found to be independent of the presence of air or other gases, and to depend entirely upon the temperature. For example, if a few drops of water be put into a dry flask at 32°, a very small quantity of vapour will be formed: if the temperature be raised, the quantity of vapour will be increased in proportion. If the temperature be again lowered, some vapour will be condensed, and the portion still remaining in the elastic form will be due to the temperature. The result is the same as respects the vapour whether air be present in the flask or not. At a given temperature the same amount of vapour is formed in a vacuum, as in the same space occupied by air, with this difference, that in a vacuum evaporation is very rapid, and comparatively slow in air, the aërial particles apparently offering some mechanical resistance to the saturation of the space with vapour. The space is said to be *saturated* when it contains all the vapour that can be produced at a given temperature: so that any addition of vapour or diminution of temperature produces condensation.

Regarding vapour as an elastic or gaseous body, its elastic force is measured by the height of the column of mercury which it will support. If a barometer tube (such as Fig. 95 or 96, article BAROMETER) be employed, filled with mercury, and standing in mercury as in the figures, and a few drops of water be introduced at the open end without removing the tube from the cistern, the water will rise up into the Torricellian vacuum, and expanding into vapour, will, by its elastic force, depress the mercury in the tube. The amount of this elastic force or tension may be measured by comparing the height of the mercury in the tube with that in a good barometer near it. The temperature of the vapour in the vacuum may be determined and regulated by surrounding the upper part of the tube with a vessel containing water and a thermometer. If the barometer stand at 30 inches, and the mercury in the tube at 29 inches, then the tension or elastic force of the aqueous vapour will be expressed by 1 inch of mercury, or $\frac{1}{30}$th part of the mean elasticity or tension of the atmospheric air. If the water in the outer vessel be heated to 212°, the whole of the mercury will be forced out into the cistern, for the elastic force of vapour of water at that temperature is 30 inches of mercury: *i. e.* it will support a column of mercury at that height, just as the atmosphere does at the level of the sea.

These experiments explain the meaning of the valuable tables given in scientific books of the elastic force of steam at different temperatures. The following is a specimen of such a table, which gives also the weight of a cubic foot of vapour at the temperature named.

Temp. Fahr.	Tension in inches of mercury.	Weight of a cubic foot.
32°	0.216	2.53 grs.
40°	0.280	3.23 „
50°	0.400	4.53 „
60°	0.560	6.22 „
70°	0.770	8.39 „
80°	1.060	11.33 „
90°	1.430	15.00 „
212°	30.000	257.22 „

The relative volatility of other liquids, and the elastic force of their respective vapours, may be estimated by their effects on the column of mercury in the barometer tube. Thus, if five barometers be placed side by side, and some water be let up into the vacuum of the first, some alcohol into the second, ether into the third, and sulphuret of carbon into the fourth, each column will be depressed by the elastic force of the vapour of each liquid at the existing temperature of the air.

As evaporation is entirely confined to the surface of a liquid, so its amount depends upon the amount of surface exposed. Thus, in certain processes in the useful arts, where crystals are formed by evaporation, or where liquids are exposed to the air for other purposes, large shallow vessels are employed, or the liquids are allowed to trickle over extended surfaces. [See SALT.] By covering the surface of water with a film of oil, evaporation is suspended altogether. The process goes on most rapidly when a dry wind is blowing over the surface of the liquid: hence in some factories where large quantities of liquids are to be evaporated, a current of hot air is passed over their surface, instead of applying fire beneath them. Evaporation is slow, when stagnant air rests on the surface of the liquid, for when this becomes saturated with vapour, the presence of this vapour puts a stop to the process. Hence the use of revolving fans, made to fly rapidly over the surface of the liquid [see BEER, Fig. 113], so that as fast as the vapour is formed it is wafted away. It will be seen, from the following table, how different the results are in still air from those obtained during wind. This table shows the force of vapour at different temperatures, and the rate of evaporation per minute from a circular surface 6 inches in diameter.

Temp.	Force in In. of Mercury.	Calm.	Breeze.	High Wind.
212°	30.000	120.00 grs.	154.00 grs.	189.00 grs.
85°	1.235	4.92 „	6.49 „	8.04 „
75°	0.906	3.65 „	4.68 „	5.72 „
65°	0.657	2.62 „	3.37 „	4.12 „
55°	0.476	1.90 „	2.43 „	2.98 „
45°	0.340	1.36 „	1.75 „	2.13 „
35°	0.240	0.95 „	1.22 „	1.49 „
25°	0.170	0.67 „	0.86 „	1.05 „

Professor Daniell, who drew up this table from the

experiments of Dalton, remarks that these amounts of evaporation are only maintained when the incumbent air is perfectly dry. If vapour be already present, as is always the case in the atmosphere of this climate, the quantity capable of evaporating at any given temperature will be the quantity indicated in the table, diminished by the quantity already in the incumbent air.

When a liquid passes into the state of vapour, there is a great absorption of heat, which becomes latent. This conversion of sensible into latent heat is necessary to the existence of a vapour, and it takes place at whatever temperature the vapour is formed. The source of heat in ebullition is supplied by the fire; but in spontaneous evaporation it is usually furnished, either by the liquid itself, or by the vessel containing it. Advantage is taken of this fact in the cooling of water and wine by means of porous vessels, named *alcarrazas*, which being filled with water, and hung up in a current of air, the fluid slowly penetrating to the outside of the vessel is converted into vapour by depriving the water within of a portion of its heat. If a wine bottle be placed in the cooler, its temperature is lowered with that of water. Wine or water may also be cooled by wrapping a wet towel round the bottle or vessel containing it, and exposing it to a draught of air. In India the bed curtains are sprinkled with water, by the evaporation of which the air is cooled. The danger of wearing damp clothes arises from the cold produced by evaporation. In the animal economy, heat is generated in the system, and given out by the body. If this heat be abstracted faster than a new supply is formed by the process of respiration, the sensation of cold is produced, whereas, if the heat be not removed exactly in proportion as it is formed, a feverish sensation is experienced. The former effect is produced by the evaporation arising from damp clothes, and the general result is what we term a cold.

By the skilful application of a known principle, some very surprising results may often be obtained. For example, if some ether be poured upon the surface of water contained in a flat vessel, and placed under the receiver of an air-pump, the ether will boil as soon as the air is removed, and its rapid evaporation will soon cause the water to freeze, thus exhibiting the singular spectacle of two liquids, one resting upon the other, the one boiling and the other freezing; in a few minutes the one entirely disappears in the form of vapour, while the other solidifies in the form of ice. Some remarkable examples of freezing will be given in the article Ice.

Various instruments have been contrived for measuring the quantity of vapour existing in the atmosphere, or its relative degrees of dampness and dryness. Those which merely indicate the presence of moisture in the atmosphere, more or less, are termed *hygroscopes;* those which measure its quantity are more properly named *hygrometers.* To the former class belong certain animal and vegetable textures which absorb moisture with great readiness, and by their changes of dimension which ensue, measured on a graduated scale, indicate roughly the amount of vapour. Thus the untwisting of a piece of catgut, or the beard of the wild oat, the elongation of a thin slice of whalebone, the elongation or contraction of a human hair, &c., have all been used. When these substances are exposed to a dry atmosphere, they give up the moisture which they have imbibed, and return more or less accurately to the dimensions which form the zero of the scale. Instruments of this kind are, however, liable to uncertainty in their construction, so that two instruments of the same kind by different makers, or even by the same maker, do not always agree in their indications, and such instruments always become deteriorated by time.

A beautiful and simple method for determining the elastic force of vapour at any time existing in the air, was adopted by Dalton, and afterwards by Daniell, who used it as the basis of his elegant hygrometer. It is well known that the moisture of the atmosphere will become condensed upon the surface of a colder body brought into contact with it. Thus, when a glass on a warm day is filled with well-water, its surface becomes bedewed with moisture. By pouring this cold water into a second glass, carefully drying the surface of the first, and returning it back again, and repeating the operation many times, or as often as may be necessary, the water becomes slowly warmer. The temperature of the water must be carefully noted with a small thermometer, as also the precise temperature at which the glass ceases to be bedewed. This is called the *dew-point,* and is in fact the temperature of water, whose vapour is of the same elasticity as that of the air of the place where the observation is made. In winter, or in very dry situations, the water may be cooled down by mixing a little ice, or salt and snow with it, and if these cannot be procured, a small quantity of sulphate of soda, or of carbonate of soda, added to the water, will reduce its temperature below that of the atmosphere, so as to produce a deposit of dew upon the glass. The glasses used should be thin. The observation may be made more precise by using a small cup of thin silver, of the capacity of half an ounce, gilt on the outside. The water is to be cooled by cautiously adding a few grains of a powder composed of equal parts nitrate of potash and muriate of ammonia, stirring it up with the bulb of a small thermometer.

But the dew-point may be most conveniently observed with the assistance of Daniell's hygrometer, Fig. 895. It consists of two thin glass bulbs, *a b*, connected together by a bent tube *c*. Enclosed in the bulb *b*, is the elongated bulb *d* of a very delicate thermometer *d e*, the scale of which rises into the arm *b c*. This bulb *b* being filled with ether, is heated until the vapour issues freely from an aperture *f* in the bulb *a*, which is then hermetically sealed. If the operation has been well performed, the ether in the bulb *b* will boil by the heat of the hand, as in the case of Franklin's pulse glass, [see Ebullition, Fig. 785,] which we have no doubt suggested this instrument to its ingenious inventor. The bulb *a* is covered

with a piece of muslin. The stand is of brass, and the transverse socket *i* at the top is made to hold the glass tube in the manner of a spring. A small thermometer *k*, inserted into the pillar of the stand, enables the observer to compare the temperature of the air with that of the dew-point. In using this instrument, the covered bulb *a* is to be wetted with a few drops of ether, the rapid evaporation of which cools this bulb, condenses a portion of the vapour within the bulb *a*, the consequence of which is that the ether in the bulb *b* immediately begins to evaporate, and in doing so, cools its exterior surface. This diminished temperature will be made evident by the falling of the mercury of the enclosed thermometer *e d*, and also by the formation of a ring of moisture on the outside of the bulb *b*, coinciding with the surface of the liquid. The exact temperature at which this ring of dew begins to form on the bulb *b*, must be noted on the internal thermometer, for that is the dew-point. The temperature will go on falling a few degrees, and dew may be plentifully formed on the bulb, but the first observation may be confirmed by noting the temperature at which the dew disappears from the bulb: this will be found to be identical or nearly so with the temperature at which it began to form, and this is the dew-point. If there should be a difference of 1° or 2°, the mean may be depended on as being accurate.

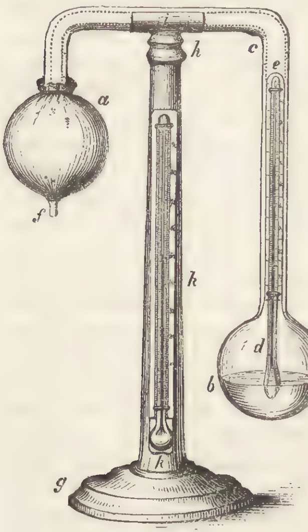


Fig. 895.

Having ascertained the dew-point, we can, by mere inspection of the tables prepared for the purpose, determine the elasticity and density of the aqueous vapour, its weight in a cubic foot of air, the degree of dryness either upon the scale of the thermometer or of the hygrometer, and the rate of evaporation. When the air is saturated with moisture, the precipitation of dew is instantaneous, for the dew-point coincides with the temperature of the air. In this country the degree of dryness measured in thermometric degrees seldom reaches 30°, that is to say, the dew-point is seldom 30° below the temperature of the air; but in the Deccan, with the temperature of the air at 90°, the dew-point has been seen as low as 29°, making the degree of dryness 61°.

Professor Daniell remarks that, "the more accurate mode of expressing the moisture of the air from an observation of the temperature and dew-point, is by the quotient of the division of the elasticity of vapours at the real atmospheric temperature, by the elasticity at the temperature of the dew-point: for, calling the term of saturation 1,000, as the elasticity of vapour at the temperature of the air is to the elasticity of vapour at the temperature of the dew-point, so is the term of saturation to the observed degree of moisture. Thus with regard to the observation in the Deccan,—

$$1.430 : 0.194 :: 1000 : 135.$$

The fourth term is the degree of moisture on the hygrometric scale."[1]

The formation of dew on the great scale of nature is a wise and beneficent arrangement for getting rid of the superfluous heat absorbed during the day, and for supplying the earth with moisture. After sun-set—and frequently, in shady places, long before—the heat absorbed by the earth begins to be radiated into space, and as this process goes on, the earth's surface becomes cooled below the temperature of the air which rests upon it. This may be easily verified on a clear night by using two thermometers, placing one on the grass and suspending the other a few feet above it. The suspended thermometer will often indicate a temperature many degrees above that of the thermometer on the grass, thereby showing the earth to be colder than the air immediately above it. Under such circumstances, the effects which are observed when a glass of cold water is taken into a warm room, are produced here: the cold earth precipitates the moisture contained in the air in the form of dew, not equally over the whole surface, as might at first be supposed, but most abundantly on those substances which need it most, such as grass and vegetables, while the gravelled walk or compact road by the side will often be quite dry. The reason for this is, that the former are good radiators of heat, and consequently cool down quickly, while the latter radiate badly, and consequently maintain their temperature. Under a cloudy sky radiation is checked, and the earth being prevented from cooling down, little or no dew is formed. On a clear night the radiation is often so powerful, and the consequent reduction of temperature so great, that the dew is frozen into what is called *hoar-frost.*[2]

EXCENTRIC. A wheel in which, whatever be the figure of its periphery, the axis is removed from the centre, is said to be *excentric*. There are various kinds of excentrics, and they are of great importance in converting one kind of motion into another; such as continuous circular motion into alternating or intermitting rectilinear motion, or into curvilinear though not rotatory motion. They also furnish

(1) Introduction to the Study of Chemical Philosophy. 1839. See also the third edition of the Meteorological Essays. 1845.

(2) The true theory of dew was first established by Dr. Wells, in a small pamphlet published in 1816: a work which Sir John Herschel "earnestly recommends for perusal to the student of Natural Philosophy, as a model with which he will do well to become familiar." This pamphlet is now difficult to procure, but the reader who desires further acquaintance with this subject will find an analysis of it in a little work entitled "The Dew-Drop and the Mist," written by the Editor, and published in 1847 under the direction of the Committee of General Literature and Education, appointed by the Society for Promoting Christian Knowledge.

means for producing from the uniform speed of one revolving shaft, rotatory motion of continually varying speed in shafts placed in connexion with it. Such an application is shown in Fig. 896, in which an excentric crown-wheel is made to produce some of the complex movements of a planetarium.[1] The crown-wheel is mounted excentrically upon a shaft which revolves with a uniform speed: a pinion driven by it is made so long that it may be acted upon either by that portion of the periphery of the crown-wheel which is nearest to its axis, or by the opposite portion of the periphery. As the distance from the axis of the crown-wheel to the nearest point of the pinion is little more than one-third of the distance from the axis to the furthest point of the same, and as the velocity of the axis or shaft is uniform, it follows that the pinion will be driven nearly three times as fast when in contact with that part of the periphery of the crown-wheel which lies furthest from the axis, as when in contact with the part which intersects it at the nearest point, while every intermediate portion of the periphery of the crown-wheel will impart a different, but intermediate velocity. Such a combination of wheels might be driven by the pinion, in which case, supposing the pinion to have a uniform velocity, that of the crown-wheel, or rather of its axis, will vary. Further variations might be introduced by making the periphery of the crown-wheel of some other form than circular.

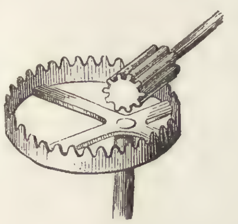


Fig. 896.

The following is a case in which a rod A B, Fig. 897, is to be raised and depressed between the guides *m n*, *o p*, by means of a continued circular motion. Let C be the centre of this circular motion, or a section of the revolving axis. Upon this axis C is fixed a circle D E excentric to it, O being its axis, and C O the degree of eccentricity. This circle D E works in a circular opening of the frame B E D, fixed to B A by a joint at B. As the axis C and the circle D E form one piece, and as C is fixed in position, the effect of turning the axis C must be to raise and depress B A between the guides, the power being proportional to a perpendicular let fall from C upon B D. When this perpendicular vanishes, which happens when the line C O coincides with B O, the rod A will be at its lowest or its highest point.

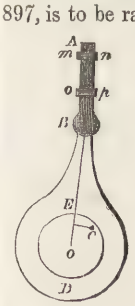


Fig. 897.

EXPANSION. See Heat.

EXPLOSION. A sudden and violent expansion of an aëriform or other elastic fluid. It differs from expansion in being momentary, whereas expansion is a gradual power acting uniformly for some time. See Gunpowder—Fulminating Powder—Steam, &c.

(1) This contrivance is by Huyghens, and is given by Professor Willis in his "Principles of Mechanism."

EXTRACT. This term is usually applied in Chemistry to the product of an aqueous decoction; but in pharmacy it is applied to that portion of any vegetable substance which had been dissolved by digesting it in any menstruum, and afterwards reduced to a thick consistence by distilling off the menstruum if valuable, or by evaporating it away if not worth preserving. Extracts are very numerous, and comprise a great variety of substances, but the nature of the ingredients varies according to the methods employed to prepare them. The greatest care must be taken to avoid injuring them by heat. Hence they should be evaporated in a water-bath, or by steam not exceeding 212°. They may also be evaporated at much lower temperatures in vacuo [See Sugar], or over sulphuric acid [See Ice]; and many of the extracts used in medicine may be so obtained, of much greater activity than when prepared in the usual way. Professor Brande remarks, that in the preparation of extracts, *uniformity* is the great object, for whether half a grain or two grains of the more powerful extracts is a dose, is of less importance than the certainty that they are as far as possible of a given power.

FACTORY. According to the definition given in the 73d section of 7th Vic. c. 15, "the word 'factory,' notwithstanding any provision or exemption in the Factory Act, shall be taken to mean all buildings and premises situated within any part of the United Kingdom of Great Britain and Ireland, wherein, or within the close or curtilage of which, steam, water, or any other mechanical power shall be used to move or work any machinery employed in preparing, manufacturing, or finishing, or in any process incident to the manufacture of cotton, wool, hair, silk, flax, hemp, jute, or tow, either separately or mixed together, or mixed with any other material, or any fabric made thereof; and any room situated within the outward gate or boundary of any factory, wherein children or young persons are employed in any process incident to the manufacture carried on in the factory, shall be taken to be a part of the factory, although it may not contain machinery. But this enactment shall not extend to any part of such factory used *solely* for the purposes of a dwelling-house, nor to any part used *solely* for the manufacture of goods made entirely of any other material than those here enumerated, nor to any factory or part of a factory used *solely* for the manufacture of lace, of hats, or of paper, or *solely* for bleaching, dyeing, printing, or calendering; and the enactments of this Act, respecting hours of labour, shall not apply to any young person employed *solely* in packing goods in any warehouse or part of a factory not used for any manufacturing process, or for any labour incident to any manufacturing process."

The factory system of England may be said to have taken its rise from the moment that the genius of Arkwright had accomplished that series of discoveries, and that clever adaptation of the discoveries

of others, which resulted in the construction of the admirable machinery used in the cotton manufacture. To accommodate that machinery, a new description of building was necessary. The spinning-wheel, and the loom, and even the spinning-jenny, if of small size, might be set up in the workman's cottage; but the water-frame, the carding-engine, &c. required more space, and also more power than the cottager could supply. Arkwright himself set the example of the sort of buildings that should be erected to work the machinery in, and to meet the new demands of the trade. He erected an extensive building in Manchester, at the cost of 4,000*l*., while in Derbyshire and elsewhere he and his partners expended upwards of 30,000*l*. in like manner. It is true that mills somewhat similar to those of Arkwright had been erected previously for the throwing of silk, but these were few in number, and of comparatively small importance.

The progress of the factory system, when once it had become identified with the cotton trade, was rapid in the extreme. Its advantages were so great, that it would have been impossible, after once experiencing them, to return to the old system. The more evident of these advantages are thus stated by Mr. Baines,—"The use of machinery was accompanied by a greater division of labour than existed in the primitive state of the manufacture; the material went through many more processes; and of course the loss of time and the risk of waste would have been much increased, if its removal from house to house at every stage of the manufacture had been necessary. It became obvious that there were several important advantages in carrying on the numerous operations of an extensive manufacture in the same building. Where water-power was required, it was economy to build one mill, and to put up one water-wheel, rather than several. This arrangement also enabled the master spinner himself to superintend every stage of the manufacture; it gave him a greater security against the wasteful or fraudulent consumption of the material; it saved time in the transference of the work from hand to hand; and it prevented the extreme inconvenience which would have resulted from the failure of one class of workmen to perform their part, when several other classes of workmen were dependent upon them. Another circumstance which made it advantageous to have a large number of machines in one manufactory was, that mechanics must be employed on the spot, to construct and repair the machinery, and that their time could not be fully occupied with only a few machines."

The introduction of steam power did not materially change the form of building required in a factory. Whether water or steam be the moving power, a cotton mill is an immense square building, frequently seven or eight stories high, with a tall chimney, and rooms perhaps two or three hundred feet in length, lighted by numerous windows, which as evening approaches are brilliantly illuminated, giving to the whole structure a remarkable appearance from without. But factories are not always of this lofty character; for near Leeds there is a striking exception in the case of one of Messrs. Marshall's flax mills, in which the stories are, as it were, placed side by side on the ground, and where the operations usually carried on one above another, are continued in an unbroken series on the floor of one enormous room, 396 feet long by 216 wide, equal to nearly two acres. The motives for this form of factory were, convenience of supervision, facility of access to machines, the power of sustaining uniformity of temperature and moisture, the absence of currents of air, which are so objectionable in ordinary mills, the simplicity of the driving gear, and the excellence of the ventilation. As this extraordinary one-story mill presents a good model of a factory where space and other circumstances will allow of its being followed, we shall describe it somewhat fully. It stands amidst the usual lofty, square, many-storied factories, from which it does not differ in the nature of the operations carried on, but in the greater convenience and simplicity of its arrangements. This magnificent room is five times larger than Westminster Hall, and seven times larger than Exeter Hall, London. The writer has, elsewhere, recorded the particulars of his visit to this mill, and the results of an attentive study of its organization, which were to the following effect:—The machinery is arranged in parallel lines, extending the whole length of the room, ample space being left for the operations of the attendants. The processes carried on are chiefly drawing, roving, spinning, doubling, and reeling, the dusty operations of dividing and heckling having been previously performed in another mill. Hot-water spinning is also carried on in this room, and with much less inconvenience than usual, in consequence of the space and abundant ventilation. The machines are mostly attended by young women; and a tablet attached to each machine states the number of spindles at work, the quantity of yarn being spun, or some other particular information belonging to the work. The lightness and airiness, warmth, and ventilation of this room, are admirable. The light is derived from the roof, which is formed of brick-groined arches, 66 in number, each 36 feet span, and supported by iron pillars to the height of 21 feet. In the centre of each arch is a conical sky-light, about 14 feet in diameter, and rising about 10 feet above the roof. From the points of these lights the used air of the room is allowed to escape. Beneath this room is an immense vaulted cellar, with brick pillars. This cellar is employed for a variety of useful purposes, one of which is, to supply hot air to the room above. This is done by means of a small steam-engine, working a large fan, which forces air through a series of 364 pipes, contained in two large steam-chests, which heat the air before it ascends into the mill. The temperature can be regulated by the quantity of steam which is admitted into the chests, or by allowing a portion of cold air to pass by without traversing the pipes. Valves and doors in the flues permit any temperature which is desired to

be attained, or that degree of moisture which is essential to the progress of flax-spinning. The cellar also contains the shafts for communicating motion to an immense assemblage of machines in the mill. These shafts are moved by a pair of steam-engines of 100-horse power. This cellar also contains the gas and water-pipes, carpenter's shop and warehouses, and a set of baths both for hot and cold water. The operatives are entitled to the use of these on exhibiting a ticket of good conduct from the overlooker. The cold baths are gratis, but for a warm bath one penny is charged. Each bath is contained in a separate room, which is lighted with gas, and the whole is under proper regulation and control. The general details of this two-acre room, and of the immense cellar beneath it, scarcely excite more surprise than the novel use to which the roof of the building is applied. The approach to this is by a flight of steps within the room, on ascending which, we come out not on an ordinary flat roof, but into a grass-field, on which sheep are occasionally seen feeding. From the surface of this field rise what appear at first sight to be numerous greenhouses, but on approaching them, the whirl of the machinery below becomes visible, and they prove to be the skylights already mentioned. The presence of a grass-field in so novel a situation admits of easy explanation. The brick arches which form the roof of the great room were first covered on the outside with a coating of rough plaster, then with an impervious coating of coal-tar and lime, and to prevent this from cracking, a layer of earth, eight inches thick, was placed upon it, and sown with grass, which flourished well in that situation. The method of draining this field is not the least admirable contrivance of this remarkable building. The iron pillars which support the roof are hollow pipes, down which the rain-water passes into the sewer beneath. The upper extremity of each pipe is covered with a grating, to prevent solid substances from entering and stopping up the channel.

Admirable as these arrangements are, it is obvious that they can seldom be carried out: in most situations the many-storied mill will be a matter of necessity, however much the one-storied mill may be a matter of choice. A cotton-mill may be like Orrell's factory at Stockport, seven stories high, forming a massive and imposing structure of main body and wings, and losing, from its great extent and importance, much of the unpleasant effect given to factories in general by a multitude of windows on a flat unrelieved surface. This mill is considered by Dr. Ure to exhibit " in the collocation of its members " an instructive specimen of the *philosophy of manufactures*. He therefore gives the following exact description of it in his work bearing that title, a description which illustrates the arrangements of cotton-mills in general, and is confirmed in every particular by our own inspection of Orrell's celebrated mill. After naming the size and importance of the building, the central portion of which is 300 feet long and 50 feet wide, while the projection of the lateral wings is 58 feet in front of the main body, he says, " The moving power consists of two 80 horse steam-engines, working rectangularly together, which are mounted with their great gearing-wheels on the ground floor, at the end of the body opposite the spectator's right hand, and are separated by a strong wall from the rest of the building. This wall is perforated for the passage of the main horizontal shaft, which, by means of great bevel wheels, turns the main upright shaft, supported at its lower end in an immense pier of masonry, of which the largest stone weighs nearly five tons. The velocity of the piston in each of these unison engines is 240 feet per minute, which by the balance beam and main wheel is made to give to the first horizontal shaft 44.3 revolutions, and to the main upright shaft 58.84 revolutions per minute. As the one engine works with its maximum force, when the other works with its minimum, the two together cause an uniformity of impulsive power to pervade every arm throughout the factory, devoid of those vibratory alternations so injurious to delicate and finely poised mechanisms. The engines make 16 strokes per minute, of 7.6 feet each, and perform their task with chronometric ease and punctuality. The boilers for supplying steam to the engines and to the warming pipes of the building, are erected in an exterior building at the right-hand end of the mill, and transmit the smoke of their furnaces through a subterraneous tunnel to the monumental-looking chimney. By this means a powerful furnace draught is obtained, corresponding to a height of fully 300 feet." Orrell's mill spins warp yarn by throstles, weft yarn by mules, and weaves up both by power-looms. " Both systems of spinning, namely, the continuous or by throstles, and the discontinuous or by mules, require the cotton to be prepared on the same system of machines, and therefore they must be arranged subordinately to the preparation rooms. This arrangement has been considered in the true spirit of manufacturing economy by the engineer. As the looms require the utmost stability, and an atmosphere rather humid than dry, they are placed on the ground-floor of the body of the building, as also in a shed behind it, to the number of about 1,000. The throstle-frames occupy the first and second stories of the main building; the mules the fourth and fifth stories, each of these four apartments forming a noble gallery, 300 feet long by 50 wide, and 12 feet high. The third story is the preparation gallery, intermediate between the throstles and mules, as it is destined to supply both with materials. Towards one end of this floor are distributed the carding engines; towards the middle, the drawing machines for arranging the cotton fibres in parallel lines, and forming them into uniform slivers, or soft narrow ribands; and towards the other end, the bobbin and fly frames, or roving-machines, for converting the said slivers into slender porous cords called rovings. These rovings are carried downstairs to be spun into warp yarn on the throstle, and upstairs, to be spun into weft (or sometimes warp) yarn on the mules.

"The engine occupies an elevation of three stories at the right hand end of the mill. The stories immediately over it are devoted to the cleaning and lapping the cotton for the cards. Here are, 1, the willows for winnowing out the coarser impurities; 2, the blowing-machine for thoroughly opening out the cotton into clean individual fibres; and 3, the lapping-machine, for converting these fibres into a broad soft fleece like wadding, and coiling the fleece into cylindrical rolls. These laps are carried to the contiguous carding-engines, and applied to their feed-aprons. The winding-machines and a few mules occupy the remaining apartments in the right wing. The attic story of the main building is appropriated to the machines for warping and dressing the yarn for the power-looms. The other wing of the mill is occupied with the counting-house, store-rooms, and apartments, for winding the cotton on the large bobbins used for the warping-frame. A staircase is placed in the corner of each wing, which has a horse-shoe shape, in order to furnish in its interior the tunnel space for the teagle or hoist apparatus, for raising and lowering the work-people and the goods from one floor to another."

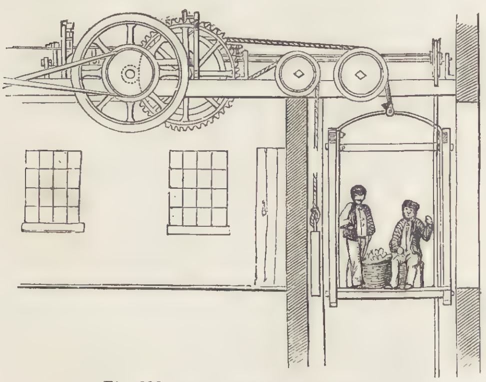


Fig. 898. THE TEAGLE OR HOIST

The Factory *teagle* or *hoist* thus alluded to, is a contrivance rendered necessary by the system of many-storied mills, to avoid the painful effort and loss of muscular energy involved in frequently ascending and descending numerous flights of stairs during the day. It is now adopted by most mill-owners, as a matter of economy as well as of due consideration for their work-people. It consists of a movable platform, capable of holding some half-dozen of operatives, and raised or lowered within an upright tunnel by machinery. The tunnel has doors in its sides, opening into the different floors of the factory, and the teagle, moving with a uniform and agreeable motion, is easily arrested at any one of these stories, while the work-people leave or enter on the platform. The same means is of course available for the conveyance of goods from floor to floor. The teagle is a strong frame-work of timber, six feet high, three sides of which are closed in with deal boards, while the fourth is left open, and faces the various doors of the tunnel. The frame is suspended by ropes from pulleys, and moved by machinery, which can be set in train with the common moving power. The accompanying illustration will sufficiently explain the action of this ingenious machine. Accidents occasionally occur in the use of the hoist, but these, as well as other accidents from machinery, are lessened in number by the care now taken to guard and fence off certain parts of machines considered dangerous. It is the duty of the government inspector, according to the act of 1844, to see that such precautions are taken, and to obtain correct returns of all accidents in a factory, which prevent the person injured from returning to his next day's work. The act also expressly requires, that if the inspector or sub-inspector shall observe in a factory any part of the machinery of any kind or description, or any driving-strap or band, not securely fenced, which he shall deem likely to cause bodily injury to any person employed in such factory, he shall give notice in writing to the occupier of the factory, or his agent, and if the occupier should object, or consider it unnecessary to fence such machinery, the matter is to be referred to arbitration, the arbitrators being persons skilled in the use of such machinery, and chosen, one by the inspector, the other by the occupier of the factory, a third being allowed, if necessary, to be chosen by the other two. If the decision of the arbitrators be, that it is unnecessary or impossible to fence the machinery in question, then the occupier will not be liable to the expenses connected with this reference: but if the decision be that it is necessary and possible for the occupier to fence the machinery, then the expenses of the reference will also fall on him.

The hours of labour in factories for women and young persons have been restricted, by the law, as amended by the act of 1850, to the interval between six o'clock in the morning and six o'clock in the evening, (including meal-times,) with exceptions during the winter months, and for the purpose of recovering lost time. On Saturday the working-hours are from six A.M. until two P.M. Respecting this latter arrangement an inspector (Leonard Horner, Esq.) thus wrote in November 1850:—"One of the greatest boons which the act of last session has conferred on the work-people, is the cessation from labour on Saturdays at two o'clock in the afternoon; two and a-half hours of continuous time, taken off that day from what could be worked under the Ten Hours' Act, being far more valuable to the work-people than the five separate half-hours from half-past five to six in the evening on the other days of the week. This boon has been acknowledged with not less gratitude by the adult males than by those whom the law takes under its protection. In some cases I have heard of, where an attempt was made to induce adult males to work after that hour, they have refused to comply, preferring the leisure to the additional pay. I have heard many emphatic expressions by the work-people of the satisfaction which this enactment has given, and the generality of masters fully admit the advantages of it to those they employ. Besides the direct benefit of their work-people having an opportunity of making their family arrangem   and having some

recreation, their freedom from work on Saturday at that early hour is very likely to lead many to a more decent observance of Sunday than was possible under the old system."

A gratifying and unexpected result of shortening the hours of labour in factories has been, that nearly the same amount of work is turned off as before. "This is accomplished," says Mr. Horner, "partly by an increased speed of the machinery, but chiefly by the closer attention which the people give to their work, and are enabled to give by the shortened duration of the daily strain upon their physical powers. In one of the cases stated to me, there had been no increase in the speed of the machinery. The manager of one of the largest and best-managed cotton mills in my district, two months ago, of his own accord, made a statement to me, which I wrote down at the time, and which I now copy from my note-book:—'We are turning off the same amount of work as we did when we worked twelve hours. When I came to this mill nine years ago, the quantity turned off in the spinning department was the same as now; and there has been no change in the machinery, no increase in the speed. I set down the keeping up of the quantity entirely to the greater attention and activity of the hands. They are able to work better by the shorter time they are at it.'"

It was thought that the smaller pay of factory operatives, resulting from shortened hours of labour, would be felt as a great grievance; but, in fact, any diminution in the amount of wages earned at the factory is compensated by what is gained in other ways; thus the females are now themselves enabled to attend to various household duties, which must be discharged by some one, and for which, under the system of long hours at the factory, they had been obliged to pay for the services of a hireling: the money formerly spent in this way is now saved by the leisure afforded to the females of a family under the ten-hours system, which enables them to perform their own duties themselves; and it is this saving of expenditure at home, which in great measure enables them to withstand a diminished rate of wages, accompanied by shorter hours of work. But some compensation for the reduction in the rate of factory wages is obtained by the male as well as the female members of a family under the present system; for they are enabled, by cultivating allotments of land and otherwise, to contribute their share towards eking out any deficiency in the amount of wages earned at the mill; and this latter advantage is much more extensively available, even in the case of factories situated in large towns, than would at first be supposed. For much more garden-ground is cultivated in the suburbs of large towns than formerly, and moreover it is no uncommon occurrence for hands who are employed at a factory, to be residing at the surrounding villages at the distance of four, sometimes five miles from their work.

A medical practitioner of long experience remarked, that the hands under the ten-hours system enjoy an advantage which you cannot appreciate in money, but to the value of which they are keenly alive,—namely, improved health. Young girls and boys who have to walk long distances to and from their work, are greatly benefited by the extra two hours, in their health, and in means of improvement and enjoyment, so that it is not uncommon to hear them say, "I had rather give up a meal a-day than go back to the long hours."

In reporting their various plans to the inspector, one mill-owner says, "Last winter I offered about 200 square yards of land *gratis* to as many as wished to have it. Twenty men accepted the offer, and I have been amply repaid by seeing that it has been a great means of enjoyment to them and their families. They have been exceedingly attentive to their small gardens, having spent in them most of the time between the stoppage of the mill at six in the evening and dark. I have now several more applications, and intend to extend my plan, until every man in my employ who wishes to have a plot has got one. Following out the idea I received from you, I have determined upon offering prizes for the best flowers, and have bought several very good framed and glazed engravings for that purpose. I also established a reading-room and library at the same time, which I am glad to say have exceeded my anticipations. Having a convenient room at liberty, I offered it to them with about 160 volumes of books. They pay one penny a-week as subscription, (those who choose to subscribe,) which sum purchases a sufficient number of newspapers and other periodicals. I believe that, merely in a pecuniary point of view, I am repaid by having better and more willing workmen; and I am quite confident it has been of incalculable service to them in every way."

The above plans are carried out in a comparatively rural district, and it may be said, "These things are all very well in such situations, but what can be done in the heart of a great town like Manchester?" Let the following account of what has been accomplished by a liberal and enlightened firm in that city be taken as an answer:—"For a number of years," says one of these estimable partners, "my brother and I had viewed with sorrowful feelings the woful state of ignorance existing in many of the mills of this extensive district; we saw that the workers evinced a very low tone of moral feeling; that their homes, to a very great extent, were ill-furnished, over-crowded, badly or not at all ventilated, and generally without those little comforts so necessary to render the home of a working man his place of rest and happiness. We found in tracing the cause of these evils, that they were mainly owing to the ignorance and intemperance of the adults who, having commenced their labours in the mill at, probably, six or seven years of age, had grown up in evil habits, and finding little comfort or attraction at home, had generally preferred the allurements of the public-house, thus perpetuating the evils of their position, instead of removing them."

The first attempt made by the masters to remedy this state of things, was to establish a Temperance

Society. Having succeeded in this, and seen it joined by more than three hundred of their people, they next directed their efforts to improve the physical comforts of the operatives. They introduced a complete system of ventilation into their works, fitting up about fifteen hundred ventilators of various kinds, suited to the different processes of spinning and weaving; the ventilation of one card-room alone costing 100*l.* The health and activity of the people were wonderfully increased thereby. One woman, about forty years of age, had long suffered from asthma by working in confined card-rooms. Every week, when she was laying out her wages in provisions, one shilling was regularly spent on a bottle of physic, to enable her, as she said, to breathe; after the ventilators were set to work, she became so much better that she discontinued the bottle altogether, and was able to breathe with comparative freedom. Open air exercises were introduced, with the same view of improving the physical condition of the operatives. An extensive gymnasium and play-ground was formed, running parallel with the large mill, and to connect this with the mill-yard, a six-feet wide promenade was made on the banks of the river. A giant-stride and swings were erected in the play-ground for the use of the boys; skipping-ropes, &c., were provided for the girls, and leaping-bars and skittles for the adults. A clear space of ground was reserved for games of marbles, merry-go-round, and other childish sports. The whole of the ground was surrounded by strong seats, where many enjoyed their meals in the open air. These steps being taken, the firm thought the way had been paved for mental and moral improvement. They therefore established a Mutual Improvement Society, in a small building near the factory yard. They supplied desks, maps, pictures, &c., and engaged two teachers, one at their own expense, the other remunerated out of the funds of the Society. Three young men employed in the concern also acted as unpaid teachers. At this institution four classes are held every evening, which, with the exception of the adult male class, are all free to the whole of the hands employed in the mill. In connexion with this Society is a library containing about six hundred volumes, the subscription to which is one half-penny per week; or, to that and a newsroom, one penny per week. These rooms are open all day, so that at meal times, or when any of the hands are waiting for work, they may pass their time in reading the various newspapers and periodicals. Tea-parties are held once a-month, and fortnightly lectures are delivered in a large room in the mill. A Savings Bank, a Co-operative Society, and other useful institutions, unite with the usual and ordinary means of knowledge in a large town to raise the condition of these people.

While many honourable instances occur of mill-owners thus turning to the best account the increased leisure afforded to their work-people, others are on record, in which the time is evidently grudged, and various attempts are made to get more labour out of the operatives, and thus to evade the operation of the act, and to gain an unfair advantage over those who strictly conform to its requirements. Various devices are employed to this end. The machinery is, perhaps, set in motion five or ten minutes before, and continued to five minutes after the appointed time of commencing and of breaking off work for meals, and this continued all through the day, gives the mill-owner about half an hour's extra work beyond that which the law allows him to get from his operatives. There is a case detailed in the report ending October 1850, in which the engineer swore that his orders from the head of the firm were to start the engine twenty-five minutes before the time stated in the notice fixed up for beginning work in the morning, to take fifteen minutes from each of the meals, and to run the engine till half-past six in the evening, instead of stopping at six. Another plan has been to find some loophole for pleading that the premises do not constitute a "factory" in the strict sense of the word, and are therefore not subject to factory laws. The definition of a factory, as given at the head of this article, is now, however, so plainly set forth, that there ought not to be any longer a doubt on the subject. The several devices alluded to, the object of which is to interfere with the operation of a most beneficial act, are altogether unworthy the character of the British manufacturer, and subject him to the contempt of his more liberal-minded brethren, as well as to sundry vexatious prosecutions which it is the duty of the inspector to institute against him.

The possibility of combining with reduced hours of labour compulsory attendance of factory children at school, was proved by the successful practice of individual manufacturers before it came to be the law of the land. Sir Robert Peel, father of the late statesman, is said to have been the first to apply the principle in his cotton works at Fazeley in Staffordshire. The Messrs. Marshall, of Leeds, were the second, and it is to the great success which attended their liberal and enlightened efforts at the very time the subject was under the consideration of Parliament, that the admission of the principle in the Act of 1833 is mainly attributed. The law as it now stands is, that no child can be employed in a factory without attending school for three hours a-day on five days of every week, and that no child can be employed in a print-work without having had at least 150 hours of schooling, given in at least thirty days in the six months immediately preceding any day that it is employed. Where the factory schools are really good and efficient, the amount of instruction given in these half days is most satisfactory; no stronger proof of which can be given than by stating that, out of 61 effective schools, where the instruction is partly administered by pupil-teachers, approved and passed by the inspectors, and possessing varied and extensive knowledge, 28 of these pupil-teachers had received no other education than that of the factory schools. An intelligent master, speaking of factory boys, says, "They are among my best scholars. Three or four who have just left school, being 13, and entitled

to work full time, had gone through the arithmetic three times, and were able to give solutions of the most difficult questions. Two others had not only worked through the arithmetic several times, but had also gone through Bridge's Algebra three times before they were 13 years of age. Their knowledge of geography, grammar, and other branches taught in the school, was also very good. I could add much to show the healthy state of education amongst the half-timers." The master here alluded to has introduced with perfect success the plan of the children buying their own books; a plan strongly recommended by Mr. Dawes (now Dean of Hereford) in his account of the King's Somborne school. The saving of expense to the school is a minor consideration in comparison with the advantages which the children derive from learning lessons at home. The plan has become popular with the parents, who seem to take great pleasure in seeing the progress of their children, and in being read to out of the excellent books taken home by the more advanced pupils. The real substantial value of the schooling becomes so evident that it makes a favourable impression on the parents also, and removes much of that indifference with which they too generally look on the efforts made to educate their children. The great amount of good manifestly accomplished by well-regulated schools makes it deeply to be regretted that their number is by no means equal to that of the imperfect and badly conducted schools at which factory children receive instruction. Unless the owner of the factory interest himself in the cause of education, the chances are that the children will be sent to the school nearest to their work, whatever that school may be. Speaking of the schools in his district, Mr. Horner is obliged to confess that out of 427 schools, 76 only—that is, not more than one-fifth—are good efficient schools; that 26 more are only tolerably good; that 146 are considerably inferior to these last; that 112 are so low in quality that the term indifferent is better than they deserve; and that 66 are not only of no value, but positively mischievous, as deceptions and a fraud on the poor ignorant parents who pay the school fees. These are schools scattered over the whole of Lancashire, and a few of them in the four northern counties. By law, therefore, children are compelled to go to school, and, of course, the reality and not the mockery of education was contemplated. But, unfortunately, the inspectors have no direct power to carry out the true object of the enactment. They can recommend and urge on the owner of the factory the duty of having the children removed from a bad school to a good one, and they can also annul a schoolmaster's certificate if he is unfit to instruct children "by reason of his incapacity to teach them to read and write;" but under terms so undefined they have scarcely any real power of interference; and the school may be held with impunity in a damp unventilated room, or without any approach to discipline or good order. This being the case, the greater responsibility falls on the manufacturers themselves, whose interest as well as duty it is to see that proper means are taken for the education of the children in their employ, and for the full development of the system which Government has devised for their benefit. Numerous are the instances where this responsibility is evidently felt, and where it has led to the most liberal and effective measures; but there are still too many mill-owners who in this respect allow things to take their own course, which is then almost inevitably a bad one. The wretched attempts at teaching which in some quarters supply the place of systematic and conscientious instruction, have doubtless led to an opinion, not unfrequently maintained and expressed,—that the attempt to educate the children, proposed by the Factory Acts, has been a failure. It is only so when good schools are not within reach: where there are good schools, not only do the parents of the children, and the owners and managers of factories, with comparatively few exceptions, willingly send them, but, as we have already said, the children make good progress: their 3 hours' daily attendance, from 8 to 13 years of age, is found sufficient to give them a very considerable amount of instruction. In a visit to a school near Oldham, taught by an able and zealous master, Mr. Horner heard a large class of factory children go through an excellent examination in English history, geography, and on the cotton-plant; the chief monitor and examiner being a factory half-timer of 12 years of age. He names other instances of superior instruction given to factory operatives in infant, day, and evening schools, embracing the ignorant of all ages; and while dwelling on the liberal and benevolent policy of mill-owners, and the numerous advantages resulting to their people, he gives it as his deliberate opinion, that no description of employment for the working classes is more desirable than that in a well-regulated factory. He adds, "I am fully persuaded that as many instances of large pecuniary sacrifices, in the establishment of schools and other arrangements for the benefit of their workpeople, may be found among the owners of factories as among any other description of capitalists, whether in trade or in agriculture: if I said, more instances, I do not believe that I should overstate the case. There are doubtless many mill-owners who take no interest whatever in their people; missing by such indifference and neglect precious opportunities of doing the greatest public good, and of conferring lasting happiness on those around them, and on themselves. But this indifference is not confined to the occupiers of factories, for the condition of the largest proportion of the working classes of the United Kingdom too clearly shows that a want of a kind consideration of the employer for the employed is too widely spread, and is the root, I believe, of many of the evils in our social state; for something more than the payment of wages is needed to establish that friendly feeling towards the master, on which the security and well-being of society so much depend."

The last remark is one which should be ever in the recollection, not only of mill-owners, but of every employer of every grade. From the man who em-

ploys thousands, to the man who employs one or two domestic servants, the law of kindness and consideration equally applies; and no amount of payment of wages will atone for the neglect of the duties which that law requires.

FALL of BODIES. See FORCE.

FAN. See VENTILATION.

FARINA. See STARCH.

FAT. See CANDLE.

FAULT. See COAL—MINING.

FEATHERS. The preparation of the feathers of various birds for ornamental purposes forms the art of the *plumassier*, the French term for the artisan who works on them and combines them into their various forms, according as they are wanted for military use, or for the purposes of the toilette. The feathers most esteemed in Europe are those of the ostrich, which are accordingly imported from the African shores in considerable quantities. The west of Europe is chiefly supplied from the northern margin of the Great Desert. Those plucked from the living animal are far more beautiful, as well as more durable, than those taken from the animal some time after death. But the feathers obtained from recently killed birds have the same qualities as the living ones, and are far superior to the cast or dropped feathers. The plumage of the male bird, as is generally the case in all varieties of the feathered race, is very superior to that of the female, the fine drooping plumes on the back and near the tail being of the purest white, while those of the female are never free from a tinge of grey near the tip. In preparing the feathers for use, they are first tied together in bundles, plunged into tepid soap-and-water, and rubbed with the hand to free them from grease. After remaining in it for a few minutes, they are washed several times in pure water, as hot as the hand can bear, to rid them of the soap. Then they are bleached by being placed for a quarter of an hour in boiling water, holding in solution Spanish white, the solution being frequently agitated during the time, and the feathers washed in pure water on their removal. The next process is to pass the feathers quickly through a bath of cold water tinted with indigo, and the final one consists in sulphuring them in the same way as straw hats are done, and then hanging them up to dry. The ribs of the feathers are scraped to render them pliant, and the filaments are curled by drawing the edge of a blunt knife over them. Feathers are made to take a variety of beautiful colours, and of these rose colour is given with safflower and lemon-juice, and deeper shades of red by a boiling bath of Brazil wood, and subsequently a bath of cudbear. Indigo supplies the blues, and turmeric the yellows, alum being the usual mordant. Various shades are obtained by mixtures of the above dyes in different proportions.

Besides the ornamental purposes to which feathers are applied, there are highly useful ones, of which we all reap the benefit in the comfortable beds they supply, and in the facility with which their quills are converted into organs of communication. For bed feathers, those of the goose are employed, being dried in the air, in the sun, or in an oven, and also beaten many times. The down of the eider duck, a bird which is only found in northern countries, is remarkable for its lightness, and is very valuable for making quilts; but this down should never be employed for sleeping on, as it thereby loses its elasticity. [See EIDER DOWN.] Goose feathers unite all the qualities required in beds, namely, softness, elasticity, lightness, and warmth. After long use it becomes necessary to purify the feathers which have been used for beds, but this cannot be done by washing, as with wool or cotton. Sometimes they are put into a large metal cylinder, the double end of which receives the fire, and then agitated with sticks and beaten in order to be employed again; this operation, however, dries the feathers very much. A much better mode of purification consists in keeping the feathers moving in rotation, during a convenient time, in a cylinder with double partitions, between which steam is introduced. The feathers are exposed during several instants to the action of the steam of water, and are then dried by simple exposure to the air.

But as in the case of the ostrich, so in that of the goose, and of all the other birds whose plumage enters into the composition of beds, the feathers plucked from the living bird are decidedly the best, in respect of all those qualities which render them valuable. Hence arises the custom of plucking the live birds four or five times a-year. There is a remarkable district of our country, in which this practice is commonly pursued. Holland, a province in Lincolnshire, comprises the greater part of that division called the *Fens*. The character of this province is similiar to the province of the same name in the Netherlands, after which it has been called. Nearly the whole of it appears to have been once covered by the sea, and only brought into its present state of productiveness by the persevering labour of its inhabitants. [See DRAINAGE.] The reedy districts which have not been reclaimed are well stocked with aquatic wild fowl, and the taking of them is a profitable employment to many persons who supply the markets of London with these delicacies. The decoys in this district are more numerous than in any other part of England, and are thus described:—"They are commonly formed around quiet pools, to which pipes made of bent willows, and covered with nets, gradually enlarging as they approach the water, are conducted. Into the large orifice of the pipes the wild birds are enticed by the tame ones, trained for that business, and who conduct them into the funnel, when the appearance of a man or his dog behind drives them to the most contracted part, where they are taken. The quantity of birds taken in some seasons is prodigious, amounting to some hundreds of thousands. They usually consist of teal, widgeon, and wild ducks; but occasionally wild geese, godwits, coots, ruffs and reeves, and whimbrels, are caught." In these fens, the keeping of geese, for the sake of the feathers, is a considerable branch of rural industry, and supplies a large part of the demands of the kingdom, both for

beds and for pens. The feathers are plucked from the birds at three, four, and sometimes five different periods in the year. This is certainly a barbarous custom; but the breeders assert that, for their own profit, they pluck only those feathers which are so near falling off as to occasion little pain; those more firmly fixed, and which have some portion of blood at their end, being of very inferior value. This, however, is contrary to the assertions already made: the young ones are plucked as well as the old ones, experience having taught that, when plucked early, the future growth of the feathers becomes greater. During the breeding season, the birds are lodged in their owners' houses in wicker pens, which are arranged in rows, frequently in the bed-chambers. A gooseherd in attendance on the flock leads them daily to water, and assists them, on their return, to get into their several cells. The attendants are acquainted with each individual goose in the flock, and can commonly distinguish them by the tones of their voices. The preparation of the quills for pens will be noticed in the article PEN.

FECULA or FÆCULA. See STARCH.

FELSPAR or FELDSPAR. This important mineral is chiefly interesting in the useful arts on account of its furnishing, by a natural process of decomposition, the celebrated *kaolin,* used in making porcelain or china ware. [See CLAY.] Felspar is composed of silica 64.20, alumina 18.40, and potash 16.95. According to some chemists it may be regarded as a silicate of alumina with silicate of potash. Felspar also furnishes some soils with potash. According to Liebig, a single cubic foot of felspar is sufficient to supply an oak copse, covering a surface of 26,910 square feet, with the potash required by the trees for five years.

FELT—FELTING. See HAT.

FEN. See DRAINAGE.

FERMENTATION. Most vegetable substances which contain starch or amylaceous compounds, also contain substances which are capable under favourable circumstances of transforming starch into sugar. In many cases these substances are developed only at certain periods of vegetation, as, for example, the cereals in germinating contain a particular substance named *diastase,* which under certain conditions, explained in our description of the process of *malting* [see BEER], transforms starch into a soluble substance named *dextrine,* and then into sugar, provided the action be continued long enough. In these successive transformations there is no change in the chemical composition of the amylaceous substance; but it becomes soluble, and is thus carried into the circulation of the plant which it assists in developing.

Ripe fruits which contain much saccharine matter also contain a particular substance named *ferment,* which has the property under certain circumstances of decomposing sugar into alcohol and carbonic acid. But in order that the ferment may produce this effect, a certain temperature is required, as is also the contact of oxygen or of the atmospheric air. If grapes be subjected to pressure under mercury, and the juice received into a bell glass also full of mercury, it may be kept during many days without undergoing any change; but if a few bubbles of oxygen or of atmospheric air be introduced, a considerable disengagement of gas takes place during two or three days, and then ceases. If after this the juice be examined, it will be found that all the sugar has disappeared, and a volatile liquid, *alcohol,* has taken its place. This change does not take place in the ripe fruit itself so long as the skin is sound and all contact of the oxygen of the air with the juices is excluded; for without the contact of oxygen fermentation cannot take place.

This ferment is also produced when vegetable or animal matters spontaneously decompose. In brewing, a large quantity of this ferment, called *yeast, barm,* or *leaven,* is produced, a small portion of which being mixed with a solution of sugar soon produces fermentation, or the conversion of the sugar into alcohol and carbonic acid gas. So also when animal or vegetable substances, such as flesh, urine, gelatine, white of egg, cheese, gluten, leguminous substances, blood, &c. are exposed for some time to air and moisture, they undergo *putrefaction,* which is essentially a fermentation, in which the sugar contained in these various substances is transformed into alcohol and carbonic acid.

All saccharine substances under the influence of ferment undergo this decomposition more or less readily, and it is a characteristic of this class of organic products. The sugar of acid fruits, which turns the plane of polarization to the left; the solid sugar of dry fruits, and glucose, are rapidly decomposed by fermentation; but cane sugar requires a longer time. It is also a curious observation which polarization has revealed, that before cane sugar begins to ferment it is changed into fruit or grape sugar. Fresh yeast always contains a notable proportion of acid, and it is this acid which first changes the cane sugar into grape sugar; but as vegetable acids require much time for this transformation, the fermenting process is necessarily slow. Yeast deprived of this acid by washing, remains for a long time without any action on a solution of cane sugar; nor does fermentation commence until the acid is formed again by the changes which take place in the yeast in contact with air and water. If, on the contrary, we add to a solution of sugar the acid liquor proceeding from the washing of the yeast, the cane sugar will be transformed into grape sugar, which will enter into immediate fermentation by contact with the washed ferment.

100 parts of grape sugar yield by fermentation 48.88 parts of carbonic acid, and 51.12 of alcohol, so that the chemical elements of the ferment do not appear in the reaction, which may be expressed in the following equation:—

$$\underset{\text{Sugar.}}{C_{12}H_{12}O_{12}} = 4CO_2 + \underset{\text{Alcohol.}}{2C_4H_6O_2}$$

The decomposition of sugar by fermentation requires the immediate contact of the yeast, as may be proved by the following experiment:—the mouth of a bottle

v, Fig. 899, containing a solution of sugar, is fitted with a perforated cork through which passes a wide tube *a b* open at both extremities, but the lower one, *b*, is closed by a piece of porous paper. A small quantity of yeast diffused through a little water is poured into the tube. In proportion as the saccharine solution penetrates the tube *a b* through the paper, a very active fermentation is developed, and an abundant liberation of carbonic acid; while in the bottle itself nothing of this kind takes place, and the sweet solution remains unchanged.

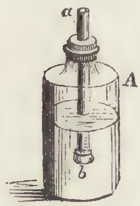


Fig. 899.

During the decomposition of sugar by fermentation, the ferment itself is destroyed, so that a small portion of this active principle is not capable of decomposing an indefinite quantity of sugar. If the quantity of ferment is too small compared with that of the sugar, its decomposition is effected before that of the sugar, a portion of which remains in the solution unchanged. If, on the contrary, too much ferment be present, the decomposition of the sugar is effected before that of the ferment, and the latter continues its action alone. If a fresh portion of a saccharine solution be now introduced, it produces fermentation therein until it is completely decomposed. The proportions which are best adapted to a rapid fermentation are 1 part cane sugar, 3 or 4 parts water, and $\frac{1}{4}$ part of fresh yeast. If the proportion of sugar be increased, the fermentation becomes less active, and it is entirely arrested in a saturated solution of sugar. In all cases sugar does not destroy more than 2 per cent. of its weight of ferment.

Weak acids employed in small quantity assist fermentation; alkalies, on the contrary, stop it, or completely modify the reaction.

Ferment appears to be a kind of microscopic vegetation, which is spontaneously developed in the organs of plants, and in a large number of azotized substances left to putrefy. It is found in greatest abundance when a solution of sugar mixed with albuminous substances of animal or vegetable origin is exposed at the ordinary temperature. After some time the liquor becomes troubled, and deposits small ovoid bodies, which increase in size until they have attained the diameter of $\frac{1}{100}$th of a millimetre. Two different kinds of ferment may be distinguished, both by the manner in which they become developed, and by their mode of action upon saccharine solutions. The first or *upper yeast* is formed in a mixture of sugar, water, and albumen, at a temperature ranging between 64° and 77°; the second or *lower* yeast is formed only at temperatures between 32° and 46°. The form of these globules and their development may be studied under the microscope by diffusing a very small quantity of yeast in a little sweet-wort, and placing a drop of this liquor between two thin plates of glass, with a little mastic varnish at the edges to prevent the evaporation of the water. These plates are put under the microscope, and by carefully adjusting a single globule of yeast in the centre of one of the spaces formed by the cross threads of the micrometer, its development may be watched and measured. The accompanying figures show the arrangement of the new globules of yeast which are formed successively round the primitive globule A 1, at the temperature of about 66°. This first globule remains for about two hours unchanged; after which there is formed from a point of its surface

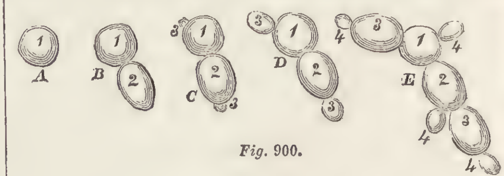


Fig. 900.

Fig. 901.

a small swelling, which continues to enlarge during six hours, until it has attained the dimensions of the first globule. See B 1, 2. This second globule produces a third, C 3, D 3, and so on, until after three days as many as thirty globules are formed round the first globule. On the fourth day there will be some increase, after which no more globules will be formed, the albuminous substances necessary to their formation being probably exhausted. Six successive generations of globules are in this way formed, and they are marked in the figures in the order of their production. The different globules appear to be in contact, but there does not seem to be any communication between them.

Fig. 902

It appears from this experiment that when an albuminous substance is added to a mixture of sugar and yeast, the sugar is not the only substance acted on, for the albuminous matter undergoes several changes, and becomes converted into leaven. This explains how it is in breweries that when the fermentation of the worts is finished, a quantity of yeast is obtained seven or eight times greater than that employed to excite fermentation. This surplus yeast is to some extent used to excite the panary fermentation in bread. [See Bread.]

In the above microscopic examination it may readily be perceived that each globule is composed of a solid envelope enclosing a liquid; it forms a kind of cellule, the inner surface of which is coated with a mucilaginous substance. If the system of globules which has attained its state of complete development be examined during several days, it will be seen that a number of minute granules are formed in each globule; (see H 4;) the rapid motion of which shows that they float in a liquid. In the course of time this interior liquid is entirely transformed into granules.

The globules whose development we have been following belong to the upper yeast, and are formed by a system of buds one upon the other. The lower yeast is composed of isolated globules disseminated in the liquid: their formation may be observed under the same circumstances as in the upper yeast, but the temperature must not exceed 44° or 46°. Each globule appears at first as an isolated point in the liquid, and is developed until it has acquired a diameter of about $\frac{1}{100}$th of a millimetre. Some observers suppose that the original globules of the lower yeast burst and discharge into the liquid the granules enclosed within them, each of these granules then becoming a globule. The process, therefore, by which the lower yeast increases or *grows*, is quite different from that by which the upper yeast is developed. If the temperature be raised to 68° or 77°, the isolated globules of the lower yeast are immediately developed by buds, thus producing the upper yeast.

The action of the two kinds of yeast upon saccharine solutions is also different. The upper yeast produces a much more active fermentation, and a very abundant disengagement of carbonic acid, while the yeast is briskly agitated in the midst of the liquid, and foams up to the surface. The lower yeast acts much more slowly, often requiring two and three months to produce a complete transformation of the sugar into alcohol and carbonic acid; nor is the ferment in rapid motion in the liquid, or sent up to the surface; but it is deposited and accumulates quietly at the bottom. This lower yeast is employed on the continent in brewing that light description of bitter ale known as *Bavarian beer*.

Observers have not been able to trace under the microscope the changes which the yeast induces in a saccharine solution, the disengagement of carbonic acid rendering such observations difficult. It has been found, however, that the yeast increases about $\frac{1}{4}$ of its weight. Its chemical composition has also changed. Fresh yeast consists of—

Carbon	47.0
Hydrogen	6.6
Nitrogen	10.0
Oxygen, about	35.0

together with traces of sulphur, phosphorus, and some mineral bases, such as potash and lime. The same yeast after it has produced fermentation contains—

Carbon	47·6
Hydrogen	7·2
Nitrogen	5·0

so that while the carbon remains nearly the same as before, the hydrogen has sensibly increased, and the nitrogen has diminished one-half.

If an aqueous solution of iodine be brought into contact with the globules of ferment, the exterior envelope does not become coloured, but the interior liquid assumes a brown colour. This may be proved by breaking the globules between two pieces of glass. The envelopes present the characters of cellulose. When a certain quantity of yeast is left in contact with a saccharine solution, so as to be completely decomposed, and the residue be ground in a mortar, and the soluble parts removed by washing with water, alcohol, and ether, a white substance is left which yields glucose by the action of sulphuric acid, and does not dissolve in alkaline solutions, which, on the contrary, immediately effect the solution of the albuminous substances of the ferment.

Yeast dried in vacuo or at a low temperature is converted into a hard, horny, semi-transparent mass, of a reddish grey colour. Its property of determining the fermentation of saccharine solutions is not lost but only suspended, for on digesting it for some time in water it again becomes active. If it be boiled for a few moments it loses its characteristic property, but will regain it by exposure to the air, provided it has not been exposed too long to the temperature of 212°. Yeast also loses its fermenting property by being mixed with alcohol, sea salt, a great excess of sugar, oxide of mercury, corrosive sublimate, pyroligneous acid, sulphurous acid, nitrate of silver, the essential oils, &c. &c. This effect, however, is not produced by certain powerful poisons, such as arsenious acid and tartar emetic; and it is worthy of remark, that these substances do not interfere with the development of certain microscopic plants; solutions of emetic exposed for some time to the air become covered with confervæ.

Such is the amount of our knowledge on the subject of fermentation. Important as this process is in an industrial as well as a scientific point of view, that knowledge is very small. The action by which yeast or ferment determines the transformation of sugar into alcohol and carbonic acid still remains without explanation. Some chemists suppose that the development and the successive changes of the globules of ferment are determined by vital force; others suppose that the ferment acts by *catalysis* or mere *contact*, and that its action resembles that by which certain mineral substances effect the decomposition of weak combinations, without being themselves decomposed, or their elements entering into the reaction. It is thus that the binoxide of manganese determines the decomposition of the binoxide of hydrogen (oxygenated water) into oxygen and water, without being itself affected. So also chlorate of potash, which does not decompose under a temperature of 1,000° or 1,100° when heated alone, becomes decomposed at a greatly reduced temperature when intimately mixed with oxide of copper or binoxide of manganese, oxides which remain unchanged in the residue. Some writers suppose, that the motions of

the particles of the ferment during their successive changes are the chief cause of the decomposition of the sugar, which motions being communicated to the saccharine particles destroy their inertia, and the elementary molecules group themselves in such a manner as to form more stable compounds.

In this article we have chiefly followed the abstract given by Regnault in the fourth volume of his "Cours de Chimie." A much fuller account of fermentation is given by Dumas in the sixth volume of his "Traité de Chimie." For practical examples of fermentation we refer to the articles BEER—BREAD—DISTILLATION—ACETIC ACID.

FERROCYANIC ACID. See PRUSSIAN BLUE.

FILE. A file may be defined as a strip or bar of steel, the surfaces of which are cut into fine points or teeth, which act by cutting, ploughing up, or abrading the substance to which they are applied. The surface operated on by the file is covered with minute irregular furrows, in consequence of the removal of particles of the material known as *file-dust;* but the state of the surface after the operation of filing depends on the size of the teeth of the file, the degree of accuracy with which they are cut, and the skill of the workman.

The varieties of files are almost endless, depending as they do upon the kind of work for which they are required. Thus files may vary in *length* from three-quarters of an inch, as in some of those used by the watchmaker, to 2 or 3 feet and upwards, as in some of those used by machinists and engineers. Watchmakers' files are of a more varied character than those of any other artisan, but they seldom exceed 4 or 5 inches in length; while the files used by the machinist are not under 8 inches in length. Mathematical instrument makers, gun makers, and those whose works are of medium size, employ files from about 4 to 14 inches in length. The length of files is measured exclusively of the tang or spike by which the file is fixed in its handle. There is no fixed proportion between the lengths and widths of files; but in general the lengths of square, round, and triangular files are from 20 to 30 times their widths taken at the widest parts; and the lengths of broad files, such as flat files, half-round files, &c., are from 10 to 12 times their greatest widths.

Files are also distinguished as, 1, *taper*, 2, *blunt*, and 3, *parallel*. The first kind are the most numerous, their length being made to taper so as to terminate nearly in a point. The second kind of files are made parallel, or nearly so, and hence terminating in a square or blunt end, are known as *blunt-pointed*, or simply *blunt* files. In both kinds, however, the section of the file is largest towards the middle, so that the sides are somewhat arched or convex. A few files are made as nearly parallel as possible, and consequently have an equal section throughout; such are termed *parallel* files and *dead parallel* files; but even in these it is very common to find them slightly fuller in the middle. In almost all taper, blunt, and parallel files, the central line is kept as straight as possible; a very few files, such as the *rifflers*, used by sculptors and carvers, are made curvilinear in their central line.

Files are also distinguished as *Sheffield-made* and *Lancashire-made*, Sheffield, and Warrington in Lancashire, being the principal seats of the file manufacture in England. The Lancashire files are mostly the finer varieties, such as are used by watch and clock makers, mathematical instrument makers, &c. These files were formerly very superior to those made at Sheffield, in the quality of the steel, delicacy of form, perfection and fineness of the teeth, and success in hardening. Of late years the Sheffield manufacturers have gone on steadily improving, so much so that Mr. Holtzapffel thinks that in files exceeding 8 or 10 inches in length, Sheffield files are nearly equal to the Lancashire; but in files not exceeding that length the superiority is considered to pertain to the latter.

Files in other respects the same, may differ in the forms and sizes of their *teeth*. In the first place, files may be *double-cut;* that is, two series of straight chisel cuts are made to cross each other, whereby an immense number of points or teeth are raised on the surface of the file. In the second place, files may be *single-cut*, that is, a number of ridges are raised square across the file by means of one series of straight chisel cuts. Such files are distinguished by the name of *floats*, the term *file* always implying *double-cutting*. In the third place, when the surface of the steel is dotted over with separate teeth formed by the indentations of a pointed chisel or punch, a *rasp* is formed. Floats and rasps are used for woods and soft materials; double-cut files for metals and general purposes.

Double-cut files are further distinguished, by their respective makers, according to the fineness of the teeth, as follows:—

Lancashire files.	*Sheffield files.*
1. Rough.	1. Rough.
2. * Middle-cut.	2. Bastard.
3. Bastard.	3. Second-cut.
4. * Second-cut.	4. Smooth.
5. Smooth.	5. * Dead-smooth.
6. Superfine.	

The sizes marked * are not commonly made, so that we may consider that there are four degrees in each scale, the Lancashire being somewhat finer. All or any one of these four varieties of double-cutting apply to every length of file, so that the number of cuts in the inch varies greatly with the length of the file, as will be seen in the following table:—

LANCASHIRE CUT FILES.

	4 in. long.	6 in. long.	8 in. long.	12 in. long.	16 in. long.	20 in. long.
	Cuts ℔ in.	Cuts ℔ in.	Cuts ℔ in.	Cuts ℔ in.	Cuts ℔ in.	Cuts ℔ in.
Rough ...	56	52	44	40	28	21
Bastard..	76	64	56	58	44	34
Smooth..	112	88	72	72	64	56
Superfine	216	144	112	88	76	64

Floats and rasps are usually distinguished as *coarse* and *fine;* but these two varieties of teeth differ, in files, according as the length varies.

Some files, such as are used for making a set-off or

shoulder, or in filing out rectangular corners, have one or more of their edges left uncut, or *safe* as they are called; such safe-edges rubbing against the work and guiding the cut part of the file, without acting on the part which they rub. In some cases the edges alone are cut, and the sides left safe or smooth.

With respect to the forms of files, their sections are derived from the *square*, the *circle*, and the *equilateral triangle*, as shown in the following figures.

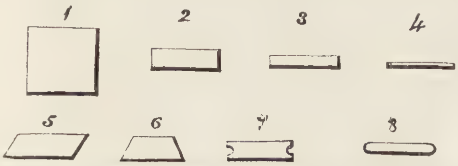


Fig. 903. SECTIONS OF FILES DERIVED FROM THE *square.*

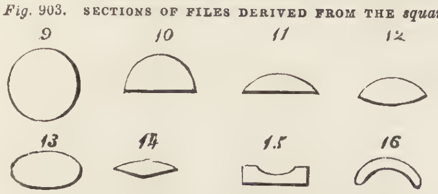


Fig. 904. SECTIONS DERIVED FROM THE *circle.*

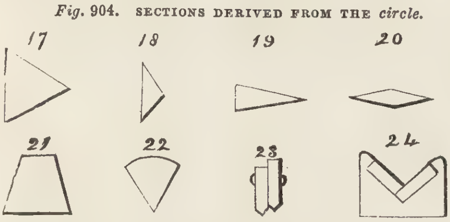


Fig. 905. SECTIONS DERIVED FROM THE *triangle.*

The names of some files are derived from their sections, as *square, round,* and *half-round* files; others from the uses to which they are applied, as *saw-files, slitting, warding,* and *cotter* files. But the files in most common use are those known as *taper* files, *hand* files, *cotter* and *pillar* files, *half-round, triangular, cross* and *round* files, *square, equalling, knife* and *slitting* files, and *rubbers.*

Taper files or *taper-flat* files vary in length from about 4 to 24 inches: they are rectangular in section, as in No. 2; they are considerably rounded on their edges, and somewhat also in their thickness; hence they are said to be *bellied:* all four varieties of cutting are applied to these files, which are in general use among smiths and mechanics.

Hand files or *flat* files resemble those last described, except that they are nearly parallel in width and less taper in thickness. They are commonly used for flat surfaces, and when more accuracy is required than in the work operated on by taper files; but in filing narrow apertures and notches, the taper file is used, first with the small end; next, the central and wider part; and then the whole length of the tool.

Cotter files vary from 6 to 22 inches in length: they are used in filing grooves for the *cotters,* keys or wedges, used in fixing wheels on their shafts; whence the name. They are narrower than hand files, and nearly flat on the sides and edges, so as to present almost the same section at every part of their length. *Taper cotter* files or *entering* files differ from the above: they taper in width and thickness, but have very little swell.

Pillar files, Section No. 3, are much narrower and somewhat thinner than hand files, and are used for lighter work, or for completing work that was begun with the hand file. They have usually one safe edge, and vary from 3 to 10 inches in length.

Half-round files, Section No. 11, are not, as the name would imply, semicircular in section, but the curvature may in general vary from the fourth to the twelfth part of the circle, the former being called *full* half-round, and the latter *flat* half-round files. Half-round files are usually taper: they vary from about 2 to 18 inches in length: the convex surface is used for various kinds of hollowed work, and the flat side for general purposes.

Triangular files, Section No. 17, also called *three-square* files, vary from 2 to 16 inches long: they are used for internal angles, for clearing out square corners and for sharpening saws.

Cross files, *crossing* files, or *double half-rounds,* Section No. 12, are circular on both faces, but of two different curvatures. They are used for filing out the *crosses* or arms of small wheels as in clock-work, the opposite sides of the tool presenting a choice of curvature.

Round files, No. 9, vary from 2 to 18 inches in length; they are usually taper, and are used for enlarging round holes: when small and taper they are termed *rat-tail* files, from the resemblance to a rat's tail; when small and parallel they are called *joint* files, from their use in filing the hollows in the joints of snuff-boxes, &c.

Square files vary from 2 to 18 inches long: they are mostly taper, and in some cases have one safe edge; they are used for small apertures, and for purposes to which the ordinary flat files are inapplicable on account of their larger size.

Equalling files, Section No. 4, are usually parallel in width and always parallel in thickness: they range from 2 to 10 inches long. In locksmiths' *ward*-files the two broad surfaces are left safe.

Knife files, Section 19, are usually made very acute on the edge, and from 2 to 7 inches long, both parallel and taper; they are used in cutting narrow notches, and in making the entry for saws and for files with broader edges; also in bevilling or chamfering the sides of narrow grooves.

Slitting files or *feather-edged* files are similar to the last, except that they have two thin edges instead of one, as in Section 20.

Rubbers are strong heavy files made of inferior steel from 12 to 18 inches in length, and from $\frac{3}{4}$ to 2 inches on each side: they are convex or fish-bellied, and are frequently designated by their weight, which may vary from 4lbs. to 15lbs. Their section is square and triangular, as in Nos. 1 and 17; or with one side rounded, such as would be formed by the union of Nos. 2 and 10, in which case they are termed *half-thick.* Their chief use is to brighten the surface of the work.

The small files used in watch-making are numerous.

In the following enumeration of the Sections Nos. 1 to 24, the names of watch-makers' files are marked in italics.

Section No. 1. Square files, parallel and taper, some of which have one safe side: also square rubbers.

No. 2. Cotter files when large; *verge* and *pivot* files when small.

No. 3. Hand files, parallel and flat files: when small, *pottance* files; when narrow, pillar files; also taper flat files.

No. 4. When parallel, equalling, *clock-pinion*, and *endless-screw* files; when taper, slitting, entering, warding, and *barrel-hole* files.

Nos. 5 and 6. *French-pivot* and *shouldering* files, which are small and stout, and have safe-edges: when made large, and right and left, they are called parallel V-files, from their use in making the hollow VVs of machinery.

No. 7. Flat file with hollow edges, used as a nail file for the dressing case.

No. 8. Pointing mill-saw file, round-edge equalling file, and round-edge joint file; made parallel and taper.

No. 9. Round file, gulleting saw file; parallel and taper.

No. 10. Frame saw file for gullet teeth.

No. 11. Half-round file: *nicking* and *piercing* files; cabinet floats and rasps; all usually taper. *Round-off* files for rounding or pointing the teeth of wheels. These files have a pivot at the end opposite the tang.

No. 12. Cross files and double half-rounds.

No. 13. Oval files; oval gulleting files for large saws. *Oval-dial* file when small.

No. 14. *Balance-wheel* or *swing-wheel* files, the convex side cut, the angular sides safe.

No. 15. Swaged files for finishing brass mouldings.

No. 16. Sir John Robison's curvilinear file. The inventor states that, having found a difficulty in filing hollow surfaces, in consequence of the scratches which the irregular cutting of even the best half-round or round files leave in the work, it became a question whether the teeth of these files could not be made as perfect as in flat files, by cutting flat strips of rolled steel plate on one side, and then squeezing them into the desired curve by a screw-press and a block-tin or type-metal swage, and, in the case of a round file, by pressing the plate round a cylindrical mandrel. In testing this proposal, Messrs. Johnson and Cammel took a thin equalling file, cut on both faces, such as No. 3 or 4, softened and bent it and then re-hardened it, thereby producing a file with a convex and a concave surface, as in No. 16. With a plate of equal thickness the central part was found to bend more easily than the edges, thus making the curve irregular; but by making the blank thinner and more flexible at the edges, the bending was successful and the section became truly circular. These curved files are now regularly manufactured.

No. 17. Triangular, three-square, saw files, and rubbers cut on all the sides.

No. 18. Cant file used for filing the insides of spanners for hexagonal and octagonal nuts, or six or eight canted bolts and nuts, as they are called.

No. 19. When parallel, *flat dovetail*, *banking* and *watch-pinion* files; when taper, knife-edge files. When the wide edge is round and safe, moulding files and *clock-pinion* files.

No. 20. Screw-head files, feather-edged files, *clock and watch-slitting* files.

No. 21. Used in finishing small grooves and key-ways: it is also named a valve file from one of its applications.

No. 22. A compound of the triangular and half-round file: similar files are sometimes made with three rounded faces.

No. 23. Double or checkering files, used by cutlers, gun-makers, and others. These files are similar in their application to the double saws used for cutting the teeth of racks and combs. [See Comb, Fig. 605, page 419.]

No. 24. Double file formed by fixing two flat files together in a wooden stock, and used for filing black-lead pencils to a fine conical point. It was invented by Mr. Cooper under the name of the "Styloxynon."

In the manufacture of files, the steel must be of good quality and highly converted; for if too soft or unequal in texture, the file itself would soon be worn down instead of the surface upon which it is intended to operate; if, on the contrary, it be too hard, the teeth become brittle and chip off at every stroke. Smith's rubbers are forged square from the bars of blistered steel as they leave the converting furnace; smaller files are forged from bars or rods of various shapes and sizes, tilted or rolled as nearly as possible to the sections required. Files of the best quality are made from cast steel. The iron bearing the mark CCND makes excellent steel for files; but the finest clock and watch-makers' files are made from the hoop L or Dannemora iron.

In forging files coke is used as the fuel. The general arrangements for forging are similar to those described in the article Cutlery, p. 480. The man called the *striker*, is furnished with a large double-handed hammer with a broad face at either end; but

Fig. 906. FORGING FILES.

the hammer wielded by the *maker* is smaller and single-handed, somewhat conical in shape, the wider end

forming the face. Three-square and half-round files are forged in grooved bosses or dies fixed in the anvil. The rod of steel being raised to the proper heat, which ought not to exceed a *blood-red*, the end is hammered until it fills the die: the maker holds the die and strikes with the small hammer; the striker standing before the anvil deals powerful blows on the heated metal, the flat faces of the hammers covering a considerable portion of the surface of the blank file at each stroke, expanding and levelling it at one operation. When the blank has been forged to the proper length, the tang is also drawn out by cutting into the blank a little on both sides with a chisel, so as to form in many cases sharp square shoulders, and then drawing out the part so cut to form the tang. The maker's mark or monogram is then stamped on. Blanks for round files are formed in a slightly conical swage: blanks for flat and square files are formed by hammering. The maker accustoms himself, as much as possible, to the forging of one description of file, in order that by the concentration of his skill and attention on one article he may attain perfection in its manufacture.

The forged blanks are carefully annealed, or *lighted*, in order to make the metal soft enough for cutting the teeth. Blanks for common files are softened in an ordinary annealing oven, but the best blanks are protected from the action of the air by being buried in sand contained in an iron box: this is slowly raised to the proper heat, which, as in the forging, ought not to exceed a blood-red.

The surfaces of the blanks are next made accurate in form and clean in surface by *stripping* or *grinding*. The former process consists in smoothing the surface of the blank with a hard file, first across and then lengthways: this is the method adopted in Warrington, where most of the files manufactured are small. In Sheffield, all the blanks above a certain magnitude are ground on large grindstones, as the more expeditious method. In a few cases, as in *dead-parallel* files, the blanks are planed in the planing machine. The blanks are slightly greased preparatory to being cut.

A few years ago the Editor witnessed the operation of file-cutting at the establishment of Messrs. Beardshaw, Stevenson and Co. of Sheffield, who have recently permitted our artist to make sketches for the three engravings, Figs. 906, 907, and 913. Writing on this subject soon after his visit, the Editor remarked in the second volume of his work on the Useful Arts:[1]—"It is scarcely possible to examine attentively the teeth of a fine file, without being struck with their beauty and regularity; but how greatly is our admiration increased when we know that these teeth are cut singly with a hammer and chisel, the workman having no other guide than delicacy of touch and precision of eye, depending however rather upon the former sense than the latter. The cutting room is a long narrow apartment with a range of windows in front, opposite which are placed a number of low stone benches for the anvils, and seats for the workmen. The hammers weigh from one to six pounds each, according to the size of the file: they are curiously formed, the handle being so placed as

Fig. 907. CUTTING THE TEETH.

to allow the mass of metal to be pulled towards the workman while making the blow. The chisels are formed of good tough steel, and also vary with the size of the file: they are somewhat broader than the file to be cut, and are sharpened to the proper angle: they are only just long enough to be held between the fingers and thumb somewhat as a pen is held, only in the left hand, the hollow of the hand being turned to the workman. But the peculiar method of handling the chisel depends in great measure on the kind of tooth to be cut. The file is held to its place on the anvil by means of a leather strap passing over each end of the file, and then under the feet of the workman in the manner of stirrups. At every blow of the hammer the chisel is made to cut a tooth, and the blows follow each other in rapid succession, the workman after every blow advancing the chisel forward by so slight a movement as to be scarcely perceptible. The chisel forms a number of angular grooves parallel to each other, the tooth being formed by the metal left between every two grooves. The skilful workman adjusts the weight of his blow to the kind of metal he is operating upon; and even in the same file, if one part be softer than another, he adapts the weight of his blow so that the teeth may be of the same size in every part. As the work proceeds he gradually shifts the file forward by loosening his tread upon the straps. When one surface is covered with single cuts, he proceeds, in double-cut files, to add a second row of teeth, making them cross the first at a certain angle, for which purpose the chisel requires to be held in a particular manner. When one side is covered, he proceeds in like manner to fill a second side; but as the teeth just finished would be injured by placing them on the naked anvil while hammering, they are protected by interposing a flat piece of an alloy of lead and tin, which completely preserves the side already formed. Similar pieces of alloy with angular and rounded grooves are

(1) Published under the direction of the Committee of General Literature and Education, appointed by the Society for Promoting Christian Knowledge.

used in cutting triangular and half-round files. Rasps, as already noticed, are cut with a triangular punch instead of a chisel, every new tooth being placed opposite a vacant space in the adjoining row of teeth. The curved surfaces of files show in a remarkable way the skill of the file-cutter: in them the teeth are formed with straight-edged chisels, many rows of short cuts being made from the top to the bottom of the file, and these cuts uniting together at their extremities thus form a complete series of lines, passing completely round the cylinder or half-cylinder as the case may be. In fine round files, as many as from ten to twenty rows of cuts are required to cover the surface with teeth; and when it is considered that there may be upwards of a hundred teeth within the space of an inch, some idea may be formed of the many thousand blows required to raise the teeth on a fine file. In double-cut files, when one row of teeth is completed, a fine file is run slightly over them, and the surface is greased to moderate the roughness before commencing the second row." In some of the double-cut gullet-tooth saw-files, Section 10, as many as 23 courses are sometimes used for the convex face, and only 2 courses for the flat one. The half-round and round files are usually cut by apprentice boys, the narrow cuts being less difficult than the broad ones. It might be supposed that all this labour might be saved by using chisels curved to the proper section, instead of straight ones; this plan has been tried and found to be quite impracticable.

The chisel used in cutting large rough Sheffield files is shown in Fig. 908. Its length is about 3 inches, the width $2\frac{1}{4}$ inches, and the angle of the edge about 50 degrees. The edge is straight, but

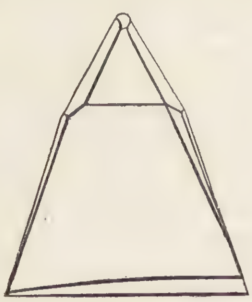


Fig. 908.

Fig. 909.

one bevil is a little more inclined than the other: the edge is rounded off in order to indent rather than cut the steel. The hammer used with this chisel weighs about 7 or 8 lbs. Fig. 909, is the chisel used for cutting the small superfine Lancashire files: it is 2 inches long and $\frac{1}{2}$ inch wide; very thin and sharpened at about the angle of 35 degrees; the edge is also slightly rounded: it is used with a hammer weighing one to two ounces. The largest files are cut by men: the smallest by women and girls.

Mr. Holtzapffel describes the operation of cutting in the following terms:—"The first cut is made at the point of the file, the chisel is held in the left hand at a horizontal angle of about 55° with the central line of the file, as at *a a*, Fig. 910, and with a vertical inclination of about 12° to 14° from the perpendicular, as represented in Figs. 909, 911, supposing the tang of the file to be on the left-hand side. The blow of the hammer upon the chisel causes the latter to indent and slightly to drive forward the steel, thereby throwing up a trifling ridge or *burr;* the chisel is immediately replaced on the blank and

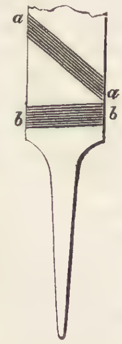


Fig. 910.

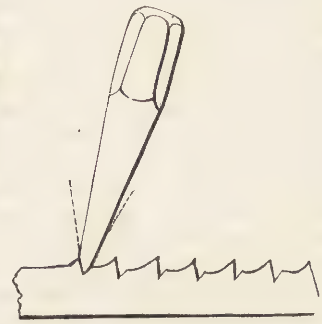


Fig 911.

slid from the operator, until it encounters the ridge previously thrown up, which arrests the chisel or prevents it from slipping further back, and thereby determines the succeeding position of the chisel. The heavier the blow, the greater the ridge, and the greater the distance from the preceding cut at which the chisel is arrested. The chisel having been placed in its second position, is again struck with the hammer, which is made to give the blows as nearly as possible of uniform strength; and the process is repeated with considerable rapidity and regularity, 60 to 80 cuts being made in one minute, until the entire length of the file has been cut with inclined, parallel, and equidistant ridges, which are collectively denominated the *first course.* So far as this one face is concerned, the file, if intended to be single-cut, would be then ready for hardening, and when greatly enlarged its section would be somewhat as in Fig. 911." Most files, however, are double-cut; that is, they have two series or *courses* of chisel-cuts. In cutting the second course, the chisel is inclined vertically as before, at about 12°, but only a few degrees horizontally, or about 5° to 10° from the rectangle, as at *b b*, Fig. 910. "The blows are now given a little less strongly, so as barely to penetrate to the bottom of the first cuts, and from the blows being lighter they throw up smaller burrs, consequently the second course of cuts is somewhat finer than the first. The two series, or courses, fill the surface of the file with teeth which are inclined towards the point of the file, and when highly magnified, much resemble in character the points of cutting tools generally, as seen in Fig. 911; for the burrs which are thrown up and constitute the tops of the teeth are slightly inclined above the general outline of the file, minute parts of the original surface of which still remain nearly in their first positions. Taper files require the teeth to be somewhat finer towards the point, to avoid the risk of the blank being weakened or broken in the act of its being cut, which might occur if as much force were

used in cutting the teeth at the point of the file, as in those at its central and stronger part."

The punch used in cutting the teeth of rasps is shown in Fig. 912. As seen in front, the two sides of the point meet at an angle of about 60°: seen in profile the edge forms an angle of about 50°, the one face being but slightly inclined to the body of the tool. Punches vary in size with the size of the rasp.

Fig. 912.

The punch in being used is sloped from the operator more than the chisel is in cutting files. By constant practice the workman hops the punch over the interval between two teeth with great rapidity and precision, producing a symmetrical arrangement of teeth with apparently very little effort. The left hand, which holds the punch, is protected by a piece of woollen cloth to prevent it from coming in contact with the anvil. The directions of the teeth vary according to the purpose for which the rasp is intended. Thus, cabinet rasps, wood rasps, and farriers' rasps, are cut in lines sloping from the left down to the right-hand-side; boot and shoe-last-makers' rasps are sloped the reverse way; gun-stockers' and saddle-tree makers' rasps are cut in circular lines. These variations are not of any importance, the only thing required being to make every tooth occupy a position intermediate between the two above it; because if the teeth followed each other in right lines, they would plough up the work and not reduce and smooth its surface.

The files and rasps are next hardened before they are fit for use. Some descriptions, however, such as are used upon wood, ivory, and other soft substances, are not hardened; such files admit of being sharpened up with a hand file. Some of the curved files used by sculptors and die-sinkers, are made of iron and case-hardened.

Before being hardened, the files are drawn through beer-grounds, yeast, or other adhesive fluid, and then through common salt mixed with roasted and pounded cow's hoof; the objects of which are, to protect the teeth from the direct action of the fire and the oxydizing influence of the air; to afford an index of temperature, the fusion of the salt showing when the hardening heat is attained; and to lessen the tendency of the files to crack on being immersed in water.

The files in the process of cutting become slightly curved, and it is necessary to straighten them before the hardening is completed. Some forms of file are apt to become curved in the act of hardening; such, for example, as the half-round file, which sometimes becomes hollow or bowed on the convex side; hence to produce a straight file it is purposely bowed, while soft, in the reverse direction. Most of the other forms of file are gradually heated to a dull red, and then straightened by striking them with a leaden hammer upon an anvil of the same material. A warped file is also in some cases straightened by being inserted between a couple of iron bars, fixed parallel a short distance apart, and then pressed in an opposite direction to the bend intended to be corrected. After the straightening, the file is placed in the fire again and heated until the salt fuses upon its surface; it is then immediately removed from the

Fig. 913. HARDENING.

fire and plunged into a cistern of cold water. The method of plunging it into the water is of importance; it is held by the tang with a pair of tongs, and immersed quickly or slowly, vertically or obliquely, according to its form; that method being adopted which has been found by experience best calculated to keep the file straight. It is, however, very difficult to prevent some degree of set or curvature in quenching the files. Each file is therefore narrowly watched, and after being plunged once into the water, if any bending is observed, it can be remedied before the file is cold, by inserting it between the bars before mentioned, pressing upon it with considerable force, and lading the water upon it with the hand: considerable curves may be corrected in this way. It is, however, in some cases necessary to re-heat the files, for which purpose they must not be placed in the forge-fire, or the teeth would be injured now that the smearing has been washed off; they are therefore held over a clear fire, or placed on a heated iron bar or over a hooded gas flame, and when straightened are quenched in oil to prevent the teeth from becoming rusty. After the hardening, the tang is tempered by immersing it in molten lead, for if the tang were left as hard as the file, it would be liable to snap off during use.

The files are next scoured with scrubbing brushes dipped into sand and water or coke dust and water; they are next put into lime-water, and left for some hours in order to get rid of every particle of salt. They are then thoroughly dried at the fire, rubbed over with olive oil containing a little turpentine, and are now considered as finished. Before packing them for sale, the foreman tests every file by striking it against a piece of steel, which is also rubbed

against the teeth; and the quality and hardness of the file, and the regularity of the teeth are judged of by the vibratory sensations thus communicated to the hand. Imperfect files called *wasters* are sorted out and sold by the pound weight; the perfect files are wrapped up separately in papers, and made up into dozens.

The cutting of files by machinery has engaged the attention of many mechanical inventors. In the second volume of the Transactions of the American Philosophical Society, a file-cutting machine is described, in which the file is fixed on a bed of lead, and a chisel fixed at the end of a lever is struck down with a hammer. This lever rises again of itself by means of a spring, and during its rise it moves a ratchet-wheel connected with the support of the bed, which is thus shifted together with the file after every stroke. In noticing this machine, Mr. Nicholson offers some very sensible observations, which mechanical inventors would do well to study; and, as they are as applicable now as in the year 1798, when they were written, we venture to quote them here. He says:—"We will suppose a very acute theorist, who is not himself a workman, nor in the habit of superintending the practical execution of machinery, to have conceived the notion of some new combination of the mechanical powers, to produce a determinate effect, and, for the sake of perspicuity, let us take the example of a machine to cut files. His first conception will be very simple or abstracted. He knows that the notches in a file are cut with a chisel driven by the blow of a hammer, by a man whose hands are employed in applying those instruments, while his foot is exerted in holding the file on an anvil by means of a strap. Hence he concludes that it must be a very easy operation to fix the chisel in a machine, and cause it to rise and fall by a lever, while a tilting-hammer, of the proper size and figure, gives the blow. But, as his attention becomes fixed, other demands arise, and the subject expands before him. The file must be supported upon a bed, or mass of iron, of wood, of lead, or other material: it must be fixed either by screws, or wedges, or weights, or some other effectual and ready contrivance; and the file itself, or else the chisel, with its apparatus for striking, must be moved through equal determinate spaces during the interval between stroke and stroke, which may be done either by a ratchet-wheel, or other escapement, or by a screw. He must examine all these objects and his stock of means in detail; fix upon such methods as he conceives to be most deserving of preference; combine, organize, and arrange the whole in his mind, for which purpose solitude, darkness, and no small degree of mental effort will be required; and when this process is considerably advanced, he must have recourse to his drawing-board. Measured plans and sections will then show many things which his imagination before disregarded. New arrangements to be made, and unforeseen difficulties to be overcome, will infallibly present themselves. The first conception, or what the world calls the invention, required an infinitely small portion of the ability he must now exert. We will suppose, however, that he has completed his drawings: still he possesses the form of a machine only; but whether it shall answer his purpose depends on his knowledge of his materials. Stone, wood, brass, lead, iron, forged or cast, and steel in all its various modifications, are before him. The general processes of the workshop, by which firmness, truth, and accuracy are alone to be obtained, and those methods of treatment, chemical as well as mechanical, which the several articles demand,—these, and numberless other practical objects, call for that skill and attention which may either lead to success, or, by their deficiency, expose him to the ignorance or obstinacy of his workmen. If he should find his powers deficient under a prospect so arduous; if he cannot submit to the severe discipline of seeing his plans reversed, and his hopes repeatedly deferred; if unsuccessful experiment should produce anguish without affording instruction,—what will then remain for him to do? Will he embitter his life by directing his incessant efforts, his powers, and resources, to a fascinating object, in which his difficulties daily increase? or will he make that strong exertion of candour and fortitude which will lead him to abandon it at once?'"[1]

One of the earliest, if not the earliest, file-cutting machine is described in Thiout's "Traité de l'Horologie." Paris. 1740. In this machine the file is attached to a screw-slide, suspended at the end by pivots, and covered with a thin plate of tin. The slide rests upon a stationary anvil, and is worked by a guide-screw which is moved at intervals the space from tooth to tooth by means of a pin-wheel. The chisel is held by a jointed arm, beneath which is a spring to throw up the chisel from off the file the moment after a drop-hammer, also fixed on a joint, has indented the tooth. The machine is worked by a winch-handle, at every revolution of which the motions of the slide and hammer are repeated at proper intervals. It does not appear whether this machine was brought into practice; but towards the end of the last century another Frenchman named Raoul produced files by a machine, the details of which have not been published. A committee of the Lycée des Arts, appointed to inquire into the merits of Raoul's files, reported them to be equal, and even superior, to the best English files. In 1836, Captain Ericsson obtained a patent for file-cutting machines, which were constructed by Messrs. Braithwaites of London, and worked by Messrs. Turton and Sons of Sheffield. Mr. Holtzapffel says that "the details of these machines display great ingenuity and skill, especially in the arrangement for holding the blanks and the chisels, and also in the introduction of templets and other mechanism, by which, in cutting taper files, the hammer is less raised in cutting the ends of the file than at the middle, so as to proportion the force of the blow to the width and depth of the cut at different parts of the file. Two machines were used for double-cut files, the bed of the one inclined to the right, of the other to the left, to give the different horizontal inclinations

(1) Journal of Natural Philosophy, vol. ii. 4to. 1799.

proper to these teeth; and a machine with a straight bed was used for single-cut floats and for round and half-round files. Considerable difficulty was at first experienced in the management of the chisels, which were then very frequently broken; but with more dexterous management it is ultimately considered that the chisels last for a longer time in the machines than when used by hand. The machines make about 240 strokes in the minute, or three times as many as the file-cutter, with the advantage of nearly incessant action, as, unlike the arm of the workman, the machines are unconscious of fatigue; moreover, to save the delay of adjustment, two beds for the files are employed, so that the one may be filled whilst the blanks in the other are being cut, and two frames for the chisels are also alternately used. Taking all these points into account, each machine is considered by the proprietors nearly to accomplish the work of ten men; but there are various drawbacks that prevent, under ordinary circumstances, any great commercial advantage in the machine over the hand process, from which considerations the patent file-cutting machines are not at present used." [1]

There is, however, one circumstance which will probably be most influential in overcoming all difficulties in the working of the file-cutting machine, and that is the rash and inconsiderate conduct of many of the file-cutters themselves. When the Editor was at Sheffield, he heard complaints from various quarters against the file-cutters; it was stated, that they were accustomed to draw money in advance, and spend it long before it was earned, in idleness and dissipation; that if the master refused to lend it, his name was "posted," and the men refused to work for him; that the file-cutters would work two, three, four, or five days in the week, and for as many hours in the day as suited their purpose, although the employer might be anxious to get an order executed; that if the masters attempted to coerce the men, violence was used, and in one establishment, gunpowder was introduced and fired by night, with a view to damage the property of the employer. Such statements as these are painful to hear, and still more painful to repeat; but he is the best friend of the operative who condemns such folly in the strongest terms, and points out to him its consequences, sooner or later inevitable. The shallow reasoning of the mob orator may persuade the file-cutters of Sheffield that files can only be cut at Sheffield, that they cannot be cut by machinery, and that the masters are tyrants who must be coerced. Now, there is no substantial objection why the file trade may not be removed from Sheffield, and files be cut by machinery. It is true that Sheffield has the converting furnaces and the well-exercised means of producing steel; but she does not produce the iron nor the fuel necessary for the purpose, so that this cannot be urged as a very powerful objection. As to the conduct of the masters, it is very possible that they do not always act with temper and discretion any more than the men: the masters seek their own interest in employing file-cutters; the file-cutters serve theirs in being employed. It is certain that the interest of the men depends upon that of their employers. It is not so certain that in this particular instance the interest of the masters depends upon the skill, steadiness, and obedience of the men; for if the men are wanting in these necessary qualities, capital will always find out and reward ingenious persons, whose inventions will sooner or later supersede skilled labour. The men may oppose the introduction of machinery, but their opposition will be feeble; the strong arm of the law will put down the one and protect the other, and file-cutting will then cease to be a manual operation. Should these few remarks (written by no unfriendly hand) fall under the notice of one of the Sheffield operatives, whose skill we both admire and respect, he is invited to receive them in the same spirit with which they are here offered.

(1) Holtzapffel: "Mechanical Manipulation," vol. ii. In this excellent work, the chapter on FILES extends to nearly 100 pages 8vo, and contains much valuable information respecting the use of files, and on works executed therewith.

A file-cutting machine was exhibited in the Russian department of the Great Exhibition. The display of hand-cut files in Class XXII. of the English department was a splendid one; but the collections of files exhibited by Austria, the Zollverein, and France, were also very conspicuous, and proved that the art receives great attention abroad. In the Danish department was a series of files manufactured of cast-steel by J. W. Naylor, of Copenhagen. The largest file (which was square, of Section No. 1) was covered with a series of file-cutters' cuts representing on one face the city of Copenhagen, on another face the operations of the forge and of file-cutting, &c. These effects were entirely produced by the file-cutter's chisel; the effect of colour and shading being given by the various angles of the teeth reflecting the light at different degrees of obliquity. The teeth of a large circular file were cut so as to represent, in a spiral going several times round the file, the maker's name, the date, wreaths of flowers, &c. This file was hollow, and contained within it a second hollow file, which in its turn contained ten others, all ornamented with wreaths, &c. The smallest file was not larger than a small needle. The Editor carefully examined all these files, and could not but admire the skill, dexterity, and even taste of the workman, showing also, as they did, the just and honest pride which he took in his art.

FILLIGREE, a style of delicate wire-work, used for ornamenting gold and silver, introduced by the Italians, who call it *filigrana*, a word compounded of *filum* a thread or wire, and *granum* a grain or bead: this is in allusion to the early practice of ornamenting the wire-work with small beads. Wire used for this purpose is seldom drawn round, but flat or angular.

The display of filligree work in the Great Exhibition was very wonderful for delicacy of workmanship and fantastic beauty. The chief exhibitors were from Sardinia, Turkey, the Ionian Islands, and Malta.

FILTER—FILTRATION. The command of an abundant supply of pure water is one of the prime

necessaries of life, and one of the most important conditions of health. Persons who reside in the country can in general select their own source of supply; and although the water which they consume may in many cases be hard instead of soft, yet it is generally free from those contaminating influences which affect the sources of supply in a great city. The daily consumption of water in the metropolis amounts to nearly 46 million gallons,[1] a considerable portion of which is derived from the Thames, a river exposed to numerous causes of contamination from the circumstance of its being the recipient of the sewage and drainage of the metropolis, and of the refuse of gas-works and other chemical factories situated on its banks. The enormous traffic on its surface further adds to the injury, by keeping solid matters in a state of suspension. Even some of the rural districts situated up the stream, being, from their proximity to the metropolis, abundantly supplied with manure, increase the contamination, by discharging into the river a drainage-water so highly coloured with soluble organic matters as to impart to the river in times of flood a distinct tinge, known as the *flood tinge*.

Where the water supply of a populous district is of bad quality, various methods are adopted for purifying it, either by the company which supplies it or by the consumer, the operations of the former being, of course, on a vastly greater scale than those of the latter. The most obvious methods of purifying water are by allowing it to repose in large reservoirs, in order that it may deposit its solid impurities before being distributed; or by passing it through a filter or strainer, the pores of which are smaller in diameter than the diameter of the smallest of the solid impurities which it is proposed to separate from the water by this method. This is a mechanical action merely, as all kinds of filtration must, in the ordinary sense of the term, be; for, although certain clays and loams, when used as filtering materials, appear to exert a chemical action, by removing organic and saline matter from solution, this property rapidly declines, and is therefore not applicable to the rapid filtration of water in reservoirs. The same remark applies to animal charcoal, which, when fresh burnt, has a powerful decolourising and deodorizing effect, but requires to be frequently renewed in order to maintain its influence. A third method of purifying water on the large scale is strictly chemical, and consists in the formation of an insoluble precipitate by the addition of alum or of caustic lime.

To discuss these and other methods of purifying water for domestic use will lead us into various details which may not appear to belong to the subject of this article; but the construction of filters and the process of filtration are intimately connected with such inquiries as the following, to which we are about to invite the reader's attention:—1. What is the original source of supply of river, spring, or well water? what is the origin of its impurities? how is hard water distinguished from soft? 2. What are the best means for purifying water on a large scale? 3. What are the best methods of purifying water on a small scale?

The water used for culinary, domestic, and industrial purposes is exclusively derived from the rain which falls upon the earth, whether the immediate source of the supply be the cistern, the well, the spring, or the river. Rain-water is usually so pure that the action of the most delicate chemical tests is required to detect any foreign substance in it; so that, if our cisterns were formed of proper materials, and the rain fell directly into them in sufficient quantity, no better water could be desired. But as the exposed surface of our cisterns is too small to collect rain-water in any quantity, it is usual to discharge into them, by means of gutters and shoots, the water which falls upon the roofs of houses; and, as these are covered with dust, insects, and other impurities collected during dry weather, the rain-water of our cisterns is thus contaminated in various ways. In some places the rain-water collected on the surfaces of extensive roofs and flats is made to pass through a bed of porous materials on its way to the cistern, and thus the solid impurities are strained and separated before the water is used by the public. Such is the case with the large cistern of the ducal palace at Venice.

Wells may be compared with cisterns; but the channels which discharge rain-water into them are not formed of masonry, brick, or metal, but of the rocks which exist immediately beneath the surface. These rocks may be porous, or may abound in minute fissures, through which the rain-water, sinking through the soil, finds a passage, and being divided into innumerable liquid threads, it dissolves and carries along with it a portion of whatever soluble matter it may meet with. Hence, the water obtained from wells is not rain-water, properly so called: it is usually as clear and limpid; but it contains nearly always certain substances in solution which differ according as the geological structure of the country differs. The same remark applies to springs: their water is rainwater, which, after having traversed strata of greater or less thickness, is sent up to the surface by the pressure of the water in the neighbouring hills or other elevations. [See ARTESIAN WELLS.] The nature and proportion of the impregnation to which spring-water is subjected depend also on the extent of its transit and the kind of rock traversed. The action of rain-water upon certain kinds of rock leads to the production of mineral springs; and if the water descends to a certain depth in the earth, its temperature will become so much raised by the internal heat, that, on re-appearing at the surface, it will be as a thermal spring.

(1) The metropolitan water companies, according to their own returns to the General Board of Health, deliver daily as follows:—

Water derived from other sources than the Thames: 25,978,445 gallons.	New River Company	15,435,617
	East London	9,036,049
	Kent	1,079,311
	Hampstead	427,468
Water derived from the Thames: 19,907,480 gallons.	Grand Junction	3,541,717
	West Middlesex	3,334 054
	Chelsea	3,940,730
	Southwark and Vauxhall	6,013,716
	Lambeth	3,077,260
		45,885,922

Every river conveys to the sea the waters of some principal source, and in its descent it gathers into its bosom the waters of numerous minor sources or tributaries. Hence the chemical composition of river-water forms a sort of mean between that of the waters of all the surrounding sources. In times of heavy rain, however, and in a water-shed of some extent, where rain falls more or less every day, the rain-water does not all filter through the earth: a portion of it flows on the surface of the ground, and down the slopes of hills, &c. with considerable rapidity. In such case it dissolves a far less quantity of mineral than it would do if it filtered through the earth, and retained for a considerable time in contact with the soluble matters of the strata. Hence it will readily be seen that river-water is more likely to be chemically pure than spring-water. Another circumstance which favours the purity of river-water, is its exposure to the air, whereby it loses that excess of carbonic acid which is present in spring-water, and so greatly assists the solution of carbonate of lime.

These remarks must, however, be taken with some limitation; for it would not be difficult to point to an arrangement of strata in which the wells and springs yield a comparatively pure water, while the neighbouring rivers are strongly impregnated with saline matter. It is, however, generally true that river-water is purer than spring or well-water. Nevertheless, the constant limpidity of spring-water and its uniform temperature are advantages in its favour when the source of supply is not far distant from the place of consumption, and would lead to its being always preferred, provided it were sufficiently abundant at all seasons to furnish the required supply. Most people prefer spring-water, and will not drink river-water, especially when the river is used as the means of carrying off the drainage of a city, although the amount of drainage may be too small to influence the composition of the water.

The advantage of greater chemical purity of river-water is counterbalanced by the absence of limpidity. The waters deposited by every shower of rain carry along with them in their precipitous course to the river various kinds of vegetable matter, earth, loam, clay, sand, and other detritus from the soil. The proportion of foreign matter thus held in suspension in the water during heavy rains and floods is different in different rivers. In the Seine the proportion rises sometimes to $\frac{1}{2000}$th; so that a person drinking three pints of unfiltered Seine water in one day, at the time of strong floods, would load his stomach with $13\frac{1}{3}$ grains of earthy matter. What would be the effect of such a dose upon the health, if continued for some time, is a question which medical men do not appear to have settled. It has been contended that, because sheep and some other animals, before they drink the water of ponds, first make it muddy with their feet, it is a sanitary process in human beings to drink muddy water. Such is not the popular opinion, which strongly, and, we think, wisely inclines to pure limpid water.

The quantity of mineral dissolved by any given water determines the extent of its *hardness*, a quality which may be either *temporary* or *permanent*. Perfectly pure water consists of oxygen and hydrogen only, and as such is perfectly *soft*. Such water kept in contact with chalk (carbonate of lime), dissolves only a small portion of that substance, one gallon of water weighing 70,000 grains taking up only 2 grains of chalk. Such an impregnation would make the gallon of water slightly hard: it would be said to have 2 degrees of hardness. Some waters contain as much as 12, 16, or even 20 grains of carbonate of lime per gallon: in which case, the solvent is carbonic acid gas, which is found in greater or less abundance in all water in the natural state. By boiling the water, the gas is driven off, and the lime (with the exception of the 2 grains actually dissolved by the water), having nothing to hold it in solution, falls down as a solid precipitate. The hardness of such water is, therefore, only temporary, and may be cured by boiling. The eminent chemists appointed to inquire into the chemical quality of the water supplied to the metropolis, found that an artificially prepared hard water containing $13\frac{1}{2}$ grains of carbonate of lime per gallon, decreased from 13.5 to 11.2 degrees of hardness by being heated in a kettle to the boiling point: boiling it for 5 minutes reduced the hardness to 6.3 degrees, for 15 minutes to 4.4 degrees, for 30 minutes to 2.6 degrees, and for 1 hour to 2.4 degrees. Thus it appears that the softening effect of boiling does not take place at once, although the greatest proportional effect is produced by the first 5 minutes' boiling. By an hour's boiling, the West Middlesex water fell from 14.6 to 5.5 degrees, and the New River water from 14.7 to 4.1 degrees. Other salts of lime, such as the sulphate, are generally dissolved in water without the intervention of carbonic acid gas, and therefore remain in solution after the water has been boiled, thus imparting *permanent* hardness.

The method of testing the hardness of these waters was by Dr. Clark's soap test. The carbonate of lime in water decomposes about 8.8 times its weight of white curd soap, and 10.7 of common yellow soap. The other salts of lime act injuriously upon soap in proportion to the lime contained in them, the soluble soap containing soda being converted into an insoluble and useless compound containing lime: thus the water is deprived of lime, or softened, at the expense of the soap. The lime in 100 gallons of Thames or of New River water thus occasions the destruction of about 34 ounces of soap, before any portion of it becomes available as a detergent. By adding measured quantities of a solution of soap to a known measure of the water to be examined, until the soap begins to give a lather with the water, or until soap bubbles appear on the surface on agitation, the proportion of earthy salt, or the degree of hardness of the water, may be ascertained.

In the water of the eight principal Metropolitan Water Companies, the hardness was found to be remarkably uniform, varying from 14° to 16°, a range not considerably exceeded at any period of the year.

During floods, however, the hardness of Thames water may fall to 8° or 9°. The shallow well-waters of London were found to vary from 32° to 80° of hardness.[1]

It is not our purpose to discuss in this article those cases where the supply of water is scanty. We suppose it to be abundant in all cases, but not pure. If charged with mechanical impurities collected during its passage to the river's bed, the most obvious method of purifying it is by filtration. In some cases, the water before its distribution is received into large depositing reservoirs, and left at rest for some hours or days in order to deposit its solid contents. This method, however, is imperfect. M. Leupold at Bordeaux found that after ten days of absolute repose the waters of the Garonne admitted into the reservoir in time of flood did not recover their usual degree of limpidity. At first the grosser particles were precipitated with great rapidity, but the finer ones remained suspended for a considerable time. In certain localities, and especially in certain seasons, water exposed to the open air for 8 or 10 days contracts a bad taste from the putrefaction of innumerable insects, which fall into it from the atmosphere, and also from the formation of vegetable matter on the surface.

When water is discoloured by clay, organic matter, and other substances more or less soluble, neither repose nor filtration will restore the limpidity. A remedy was proposed about the middle of the last century, which consisted in throwing into the water a small quantity of alum, the effect of which is to produce an almost immediate precipitation of the earthy matters held in suspension. M. Darcet found that the addition of $7\frac{1}{2}$ grains of alum to 1 quart of the muddy water of the Nile made it perfectly limpid in the course of an hour. So small a quantity of alum would not be injurious, especially when it is considered that its efficacy consists in its being decomposed: the alumina of the salt falls down with the precipitate: a portion of the acid of the salt is also saturated by the carbonate or bicarbonate of lime contained in the water; and in passing into the state of an insoluble subsulphate or other compound, is precipitated, and in the act of falling drags down mechanically the earthy particles in suspension. The alum may be employed in powder or in the lump. In the latter case a large crystal is attached to the end of a line, and moved through the water in all directions near the surface; removing it as soon as bulky flocks appear, for the formation of this precipitate is a sign that a sufficient quantity of alum has been used. When powder is used, the proper proportion should be weighed out and sprinkled over the whole surface of the water, which must not be agitated. The alum may also be dissolved in a small quantity of water and sprinkled over the surface, then gently agitated and left to repose. This last is the most rapid method.

(1) Report by the Government Commission [Professors Graham, Miller, and Hofmann], on the Chemical Quality of the supply of water to the Metropolis. London, 1851.

This method of purifying water is too refined to be trusted to any hands but those of a scientific chemist. It does not appear to be adapted to all waters, for certain minutely divided substances may escape the action of the alum, and remain suspended after the precipitate has been deposited. If the alumed water require subsequent filtration, then the use of alum appears to be a needless expense. Moreover, alum, however small in quantity, alters the chemical purity of the water by the introduction of a salt not naturally contained in it; and although this salt may be inert in certain proportions, it is easy to conceive that through the ignorance or carelessness of persons appointed to conduct the process, those proportions may be increased to an injurious extent. It is also an objection that the sulphuric acid of the alum, by converting the carbonate of lime of the water into sulphate, induces a hardness permanent in boiling.

The use of alum as a purifier has been revived in our own day. The Thames, like other rivers, becomes turbid in times of flood, acquiring a yellow *flood-tinge*, which is only very partially removed by sand-filtration. This discolouration appears to be due to the compound of clay and organic matter washed out by the Brent, from the extensive and highly manured field of the London Clay Formation, which it drains. This clay tinge resists the action of acids, and does not even fall down with carbonate of lime precipitated in the water. It can, however, be removed by alum, 7 grains of that salt to the gallon of water being sufficient in general to precipitate the clay completely, and to produce a perfect discolouration.

The use of caustic lime is less objectionable than alum, for the purpose of softening and purifying water by removing from it carbonate of lime, and a portion of the organic and colouring matter. Carbonate of lime is held in solution by the free carbonic acid gas dissolved in the water; by adding caustic lime, either in the form of lime-water, or of the dry hydrate, the carbonic acid immediately combines with the lime, converting it into insoluble chalk or carbonate of lime, which is precipitated together with the carbonate of lime originally held in solution. At the Mayfield Print-works in Lancashire, 300,000 gallons of water are thus purified every day, at a trifling expense and with little trouble. A careful series of experiments conducted by Messrs. Graham, Miller, and Hofmann, proved "that the means of conducting this process are certain in their results, and sufficiently simple to be left to the execution of a workman of ordinary intelligence. The precipitation of the carbonate of lime was terminated within 24 hours, and the water, if free from turbidity before the liming, continued in that state, but if originally turbid, it remained so, and required filtration besides the liming to make it clear. The New River and Thames waters were softened in this way to an average of about $3\frac{1}{2}$ degrees of hardness, or to a lower point than by an hour's boiling."

This process was tried on a large scale at the Chelsea Water-works. The usual supply of water

pumped up from the river, was run into the first reservoir together with a small stream of milk of lime flowing from a wooden cistern. The intermingled streams passed on into one of the great settling reservoirs, to the extent of from 3,000,000 to 4,000,000 gallons, or nearly a day's supply. The quantity of lime was regulated by testing the water in the reservoir by a drop of nitrate of silver, which shows if the dose of lime has been exceeded by the formation of a brown-coloured precipitate. After subsiding for 24 hours or longer, the water was passed through the sand-filters and distributed. The degree of hardness in five such experiments, before and after the softening process, is stated in the following table, by Mr. J. Simpson, Jun. the resident engineer.

THAMES WATER AT THE CHELSEA WATER-WORKS.

1851	Degrees of Hardness.		Remarks.
	Before liming.	After liming	
Feb. 24	14.0	4.5	The river was in good condition. The mixing was completed in 10 hours.
March 1	14.1	3.75	The river was in good condition. The mixing was completed in 9¾ hours.
... 18	10.5	5.0	The river was in flood, and the flood-tinge was retained after liming.
... 22	11.6	4.8	Recovering from flood. The yellow flood tinge not removed.
April 17	15.5	3.6	The river in an average condition.

From these experiments, and from the success and simplicity of the liming process, the commissioners conclude that this process might be made to fall easily into the routine operations of water-works without being attended with any peculiar difficulty on the large scale. The softening of Thames water in its ordinary condition by this process, to a point under 4 degrees of hardness, appears to be perfectly practicable. The water of the experiment of the 17th of April was analyzed before and after the liming. The whole fixed constituents contained in one gallon of water were found to be reduced from 24.07 to 8.31 grains, and the organic matter from 2.50 to 1.60 grains: the quantity of lime-salt present, considering it all as carbonate, was reduced from 13.65 to 2.63 grains. The softened water was clear and bright, and had acquired neither odour nor taste from the process. The cost of the process is estimated at about 20*s.* for one million gallons, and if generally adopted would add about 4 per cent to the price charged to the consumers. It must, however, be remembered that the liming process, even when combined with filtration, does not remove the yellow flood-tinge of Thames water, nor the objectionable taste of vegetable which such water has at the times of flood.

We come next to notice the methods of filtering water on a large scale.[1] Filtration may be described as of two kinds, one which is effected by the *surface* of the filtering material, and the other in which the *mass* of the filtering material operates by the retention of the solid particles of matter. If we pour rainwater upon a paper filter, such as is used by the chemist, it will pass through freely for a certain time; but as the minute impurities contained in the water accumulate on the paper, they gradually close up its pores, the water passes through more and more slowly, until at length it is arrested altogether. So also, when a mass of sand is employed as a filtering material, the minute impurities suspended in the water are arrested at various depths, and at length entirely choke or fill up the pores of the sand, and the water ceases to pass through. Hence, in order that filtering may be successfully kept up, it is necessary to provide means for maintaining a constant porosity in the filtering material. The quality of the filtered water depends on the minuteness of the impurities to be separated, and on the diameters of the pores of the filtering material. If these pores are less than the smallest diameter of the solid impurities, they will be retained, and the water will pass through clear. If, on the contrary, the solid impurities be of smaller diameter than the pores, they will pass through with the water, and the filter will be worthless. The filtering material must also be of such a kind as not to communicate any impurity to the water, and not to alter in mechanical texture by prolonged use.

In filtering on a large scale,—for the supply of a city, for example,—the cost and durability of the filter are important considerations. On the great scale of nature, the rocks which filter the water as it falls upon the surface of the soil constitute a vast permanent filter, the durability of which arises from the great extent of superficial or subterranean surface concerned. It might at first view appear to be easy to imitate this natural operation, and pass the muddy water of a river through the porous rock or sand which forms its banks; but this is often a costly proceeding, on account of want of permanence of and artificial structure so contrived. Toulouse is supplied with water from the Garonne in this way, and it has cost upwards of 40,000*l.* at various times for supplying a city of only 50,000 inhabitants. The cause of failure in this and other instances arises from the fact already noticed, that, when water filters through sand, it deposits its solid impurities to a certain depth between the interstices of the sand, rendering it necessary from time to time to renew the filtering surface. Unless this be done, the bed becomes impermeable, or, at least, not sufficiently porous to afford an abundant and permanent supply of filtered water. This is illustrated by some experiments, conducted by Mr. Wicksteed. A sand filter which yielded at the rate of 10 the first week, yielded 9 the second week, 6 the third week, and only 2 the fourth week; so that a large *natural filter* (as this description of filter is called) may go on for some years yielding a good supply of water, and then gradually diminish its supply until it ceases altogether. Hence the construction of these so-called natural filters requires much caution on the part of the engineer; and it will always be difficult, if not impossible, to calculate beforehand the amount of

(1) In this part of our subject we have been assisted by the First Report of the Commissioners of Inquiry into the state of large towns and populous districts. 1844. In the Appendix is a report on the Filtration of Water, by B. G. Sloper, Esq.

water which a natural filter proposed to be erected will yield.

A second system of filtration on a large scale consists in the formation of extensive beds of sand, of great thickness, resting on beds of gravel, &c. At intervals of time, from ten to fourteen days, the water is run off, and the filth which had accumulated during filtration is scraped off with a certain thickness of the sand of the filtering bed. Once or twice a-year the whole of the sand removed is replaced. This method is costly, and not altogether satisfactory. The expense of filtration at the Chelsea Water-works, on this system, was estimated in 1840 by Mr. Simpson as follows:—

First cost, exclusive of land..........................	£11,700
Annual cost of raising water on filtering bed	800
Annual cost of cleansing and renewal	800
5 per cent interest on outlay of capital..........	585
Annual cost, &c.	£2,185

The quantity of water filtered was originally stated to be 2,300,000 gallons daily. This was increased to 3,136,320 gallons, or 72 gallons per superficial foot of the filtering bed. The quality of the water is said to vary with the state of the bed. Immediately after the removal of the dirt and about one inch of sand at each cleansing, the pores may be said to be open. About two feet depth of water is then run on the filter, and as the filtration diminishes by the obstruction of the pores, the depth of water is increased to augment the pressure. The filth then accumulates on the surface of the filter, so that, before the water can be filtered, it must pass through this objectionable material.

Mr. John Graham, of the firm of Thomas Hoyle and Sons, stated in his evidence before the Committee the method of filtering the water of the muddy stream for the use of the bleach-works at Dukinfield. Arrangements were made for filtering 48,000 gallons per hour, or half a million gallons per day; this being the daily consumption in $10\frac{1}{2}$ hours. The water is first received into two reservoirs of subsidence, one about 4 feet and the other about 11 feet deep, having together about 2,000 yards of superficial surface. The water remains in these reservoirs from 1 to 2 days before it passes to the filters. These reservoirs are washed out once in 2 or 3 years, at an expense of from 3*l.* to 4*l.* for the two. There are two filters, one of which has an area of 1,056 square yards, and the other of 969 square yards. During some months of the year, the quantity of water passed through these filters every 24 hours exceeded 800,000 gallons. The impurities which collected on the surface of the filtering beds were removed more or less frequently, according to the state of the river and the quantity of water filtered: at some seasons the surface was cleaned only once in three months, at other times once a-week; the average being once a-fortnight. At each time of cleaning, the impure coating on the surface is removed, to the depth of half an inch, by means of

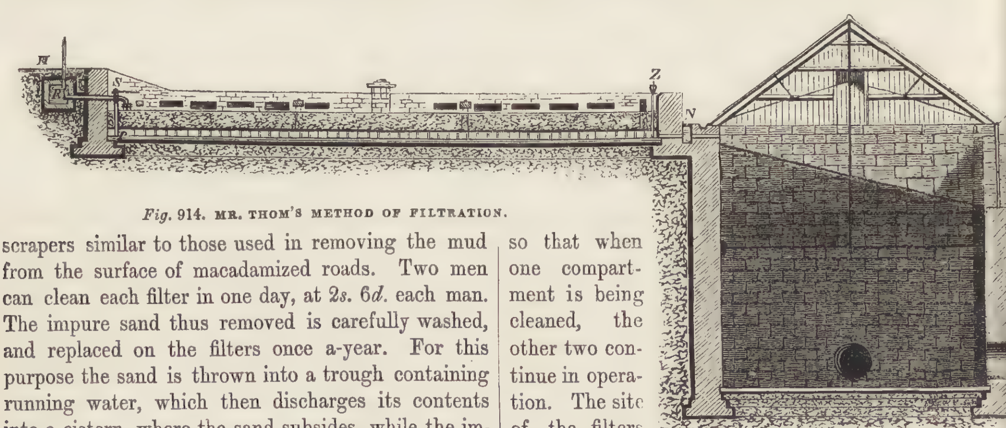


Fig. 914. MR. THOM'S METHOD OF FILTRATION.

scrapers similar to those used in removing the mud from the surface of macadamized roads. Two men can clean each filter in one day, at 2*s.* 6*d.* each man. The impure sand thus removed is carefully washed, and replaced on the filters once a-year. For this purpose the sand is thrown into a trough containing running water, which then discharges its contents into a cistern, where the sand subsides, while the impure water overflows at the extreme end of the cistern. This washing and replacing of the sand costs 40*l.* per annum. The original expense of two reservoirs and two filters was about 1,200*l.*, including everything connected with them, such as gravel, sand, valves, cisterns, &c. The total expense for settling and filtering half a million gallons of water per day was estimated at 156*l.* per annum.

A modification of this system, by Mr. Thom, has been introduced at Greenock, Paisley, and Ayr. Mr. Thom's self-cleaning filters were described by him in 1843 to the Commissioners for inquiring into the state of large towns. Fig. 914 will give some idea of the filter erected at Paisley. This filter is 100 feet long and 60 broad, and is divided into three compartments, which may be made to act together or separately, so that when one compartment is being cleaned, the other two continue in operation. The site of the filters is on a piece of level ground, excavated to the depth of 6 or 8 feet, with retaining-walls all round. The bottom is laid about a foot deep with strong stiff puddle, over which pavement is laid, so as to be impervious to water. The walls are also joined with cement, and puddled behind, so as to be water-tight. The bottom is divided into drains, or spaces, 1 foot wide and 5 inches deep, by means of fire-brick laid on edge and covered with flat tiles of the same material, perforated with small holes, rather more than $\frac{1}{10}$th inch in diameter, and placed very near each other. There is also a space of $\frac{1}{4}$th inch left open between the ends of the bricks which support the perforated tiles, and their upper edges are little more than 1 inch broad, in order that there may be little or no space left without holes, and nothing to prevent the water

spreading equally over every part of the bottom of these drains. This is particularly necessary when the filters are being cleaned by the upward motion of the water. The perforated tiles or plates are covered to the depth of an inch with clean gravel, about $\frac{3}{16}$ths inch diameter: upon this are placed five other layers of gravel, each of the same depth, and each succeeding layer a little finer than the preceding one, the last being coarse sand. Over this, to the depth of 2 feet, is placed very clean, sharp, fine sand, a little coarser than that used in hour-glasses: about 6 or 8 inches in depth of this fine sand is mixed with animal charcoal, ground to the size of coarse meal, each particle being about $\frac{1}{16}$th inch diameter. Water is admitted into the filter from collecting reservoirs or regulating basins by means of a stone pipe H and iron pipes R S P, connected therewith and with the top and bottom of the filters. Near the top of the iron pipe at S is a valve by means of which the water is made to enter at the top or at the bottom of the filter at pleasure. There is a longitudinal drain or pipe N between the filter and the pure-water basin, communicating with both; and on each of the openings between this pipe and the filter is a stop-cock, to close the communication when necessary. There are also two drains for carrying off the foul water when the filters are being cleaned, and another for preventing the water from rising too high in the filter. The action of the filter is as follows:—The sluice R and the valve S are opened, and the water permitted to flow through the filter into the drain N below until it becomes quite clear. When first set to work, this will take 2 or 3 days, unless the gravel and sand had been carefully washed before being put into the filter. Water will now flow copiously from the filter for some weeks, (the time being shorter or longer according as the water is more or less turbid on entering it,) and when the quantity begins to fail, the stop-cocks Z are closed, and the valves S raised. The water then enters *below*, and fills all the drains; and having a head pressure of several feet, it will force its way *up* through the sand to the top, and in its passage raise the scales or particles of mud which had been deposited in the downward passage, and carry them into the foul-water drain below. If the sand at the surface is stirred by a fine-toothed rake after the water has been raised above it, and a little additional water be admitted on the top, it will facilitate the operation of cleaning, as the mud is always deposited on the very surface of the sand. By this means the sediment will be carried off, and the water pass through quite clear again in a few hours: the valves at S should then be lowered, the stop-cocks at Z opened, and the operation of filtering proceeded with as before. The quantity of pure water produced regularly every 24 hours by this filter is said to average 106,632 cubic feet. The expense of such a filter to a town of 50,000 inhabitants is estimated at about 800*l*.

It is stated that, in practice, the simple return of the current of water upwards, even under a pressure of 26 feet, does not suffice to cleanse the filter, nor, in some cases, to remove even one-tenth of the dirt; that it requires violent agitation to dislodge and detach the filth from between the grains of sand. In cases where the supply of water was limited, the large quantity required for cleansing the filter would constitute a formidable objection to this plan, supposing it to be otherwise perfect. Another objection to these filtering-beds on a large scale is the great extent of ground which they occupy. The 15½ millions of gallons of water supplied daily by the New River Company would, if filtered on this plan, require upwards of 12 acres of ground for the filtering-beds, slopes and intervals, engine-room, &c.

The filter invented by M. Maurras is free from some of the objections which apply to the filters already noticed. The filtering material is sand, of various degrees of fineness, and the arrangement will be understood by referring to Fig. 915, which repre-

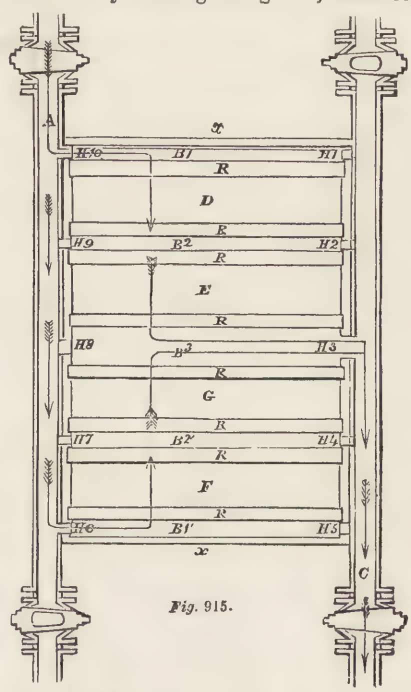


Fig. 915.

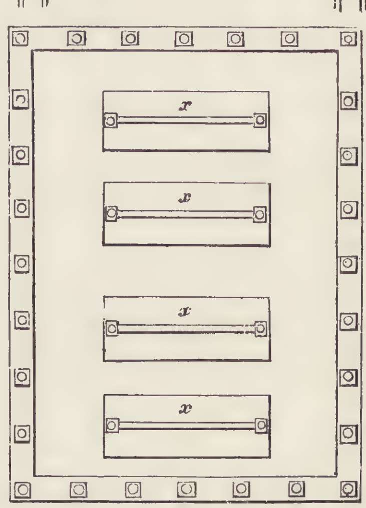


Fig. 916.

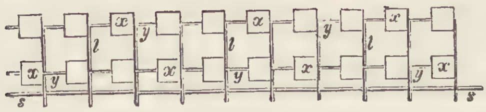


Fig. 917.

sents a section of a double-action filtering-machine, acting *per ascensum et descensum.* Fig. 916 shows the exterior of the case, which is made of iron, and water-tight, with the doors *x x* for the introduction of the sand. Fig. 917 is a plan of a double range of filters: *x x* are the filters, *y y* the supply pipes, *l l* eduction pipes of filtered water, and *s s* reservoir of filtered water. The entrance for the dirty water into the case is by the pipe A, Fig. 915; the exit for the filtered water, by the pipe C. The water in its passage through the box follows the direction of the arrows, and divides into two currents, one traversing the filtering-beds D of the coarser sand, E of the finer sand; the other current traversing the beds F of the coarser sand, G of the finer sand, meeting in the central chamber B^3, and passing off, filtered, by the cock H^3 and pipe C. B^1, B^2, B^3 are water-chambers communicating with the pipes A C by sluice-cocks at H^1—H^{10}; by means of which cocks the direction of the current of water may be varied at pleasure. The efficacy of this filter mainly depends on the simple manner in which the sand of the filtering-beds is retained, and prevented from escaping with the water under the pressure of the filtering water and the severe shocks which are required to detach and discharge the dirt from the filtering-beds. The filtering sand is retained by means of retaining-boxes R R. These are closed boxes, the upper and under surfaces of which are pierced with small holes of a certain diameter, which may be represented by 5, and filled and tightly packed with riddled sand of a diameter which may be called 6, and consequently incapable of passing through the small holes of the pierced plates of the retaining-box. Thus the sand in these boxes is a large-grained sand, easily retained; but the interstices between its grains are sufficiently small to retain the fine-grained sand of the filtering-beds. In this way the difficulty hitherto experienced of retaining fine sand is entirely overcome. The finest silver sand has been retained in an experiment of 3 months' filtration, under a pressure of a column of 60 feet of water. This method also admits of cleansing at intervals by the return of a current, and the shocks given by suddenly stopping it off, or meeting it by a reverse current having equal velocity. This is done by means of the sluice-cocks H^1—H^{10}, four of which being arranged to open and shut simultaneously, suddenly change the direction of the current, by which a violent agitation is produced between the pores of the filtering sand, and the dirt is dislodged and carried away. Hence it will be seen that the filtering material is sand of various degrees of fineness, so arranged that it cannot escape from its position in the machine; and, that the dirt is removed at intervals, and the porosity of the filtering sand restored. The machine represented in Fig. 915 is 5 feet 6 inches × 5 feet 6 inches, having a filtering surface of 60 superficial feet, capable of filtering 150,000 imperial gallons in 24 hours, with a head of water 12 feet 6 inches. According to some experiments made with one of these filters at the New River Head, Mr. Sloper estimates the cost of filtration in 24 hours daily at 2,600*l.* per annum, or 12 hours daily 4,000*l.* per annum; the delivery being 11,000,000 imperial gallons daily for 313 days of the year, the cost of filtration becomes by the first estimate 1*d.* for 5,500 gallons, by the second, 1*d.* for 3,600 gallons.

In coming now to notice the construction of small filters for domestic use, such a multitude of inventions and contrivances start up to view, that the difficulty is how to choose and where to begin. There are certain classes of subjects upon which the genius of inventors seems to run riot. *Filters* form one of these classes: *Fire-escapes* another. In either class, examples are as numerous as the attempts to solve the problem of perpetual motion, or to square the circle. Almost every kind of porous substance has been enlisted into the service of filters. The animal, the vegetable, and the mineral kingdoms have each contributed. Animal charcoal, sponge, and flannel; vegetable charcoal, cotton, straw, hemp, sawdust, shavings of wood, branches and leaves; various kinds of porous stone, sand, powdered glass, zinc and iron filings—are a few only of the filtering materials that have been used, and the methods of disposing them are as various as the substances themselves. It is necessary, however, to state at once, that in describing domestic filters, we shall scarcely notice those in which the filtering material is organic (except in the case of charcoal). It is true that filters of cotton, of wool, &c., have been tried for some time with apparent success, and have been favourably reported on by a commission appointed by a learned society. Their failure, however, arose from a cause which had not operated when the report of the commissioners was published. It was found that an animal or vegetable substance after being exposed for some weeks to constant moisture underwent decomposition, and imparted impurities of its own to the water which it was intended to purify and render potable. The wool-filter was made of mill-puff, which, being compressed, formed an excellent filtering material as far as minute porosity was concerned. It was used for filtering the water which supplies some of the fountains of Paris, to which the inhabitants resort for their usual supply; but after an extended trial, the defect which belongs to all organic substances as permanent filtering materials became too evident to be disregarded, and its use was discontinued.[1] Asbestus cloth has lately been proposed as a filtering material; and it is scarcely necessary to say that this is free

(1) It is curious that this defect of organic substances used as filtering materials should have escaped the notice of that keen and accurate observer Réaumur. In 1745, M. Amy arranged sponge and other organic substances in vases, in alternate layers with sand; and in July 1749, Réaumur wrote the following certificate:—"J'en ai eu plusieurs, et à la fois, dont chacune avait été garnie par lui-même d'un filtre différent, les unes d'éponges, les autres de coton, les autres de laine, les autres de soie, et les autres de sable: elles ont toutes donné constamment une eau très claire et très limpide."

from the objections which apply to flannel, cotton, &c. A mixture of charcoal and sand, or those substances arranged in alternate layers, is a favourite arrangement with filter-makers. The charcoal, however, is chemically as inert as the sand, and about as efficacious as a mechanical filtering material. In order for a charcoal filter to act chemically, a fresh supply of new-burnt animal charcoal ought to be used about every two days, a condition which evidently could not be complied with in a domestic filter, which, like ventilators and other salubrious contrivances, ought to be nearly, if not quite, self-acting, conferring positive benefits with very little trouble.

The Japanese and Egyptians appear from a very early period to have used vessels of sandstone, or of unglazed earthenware, for the purpose of filtering water. The stone was hollowed out into the form of a mortar, or was made egg-shaped, small projections being left at the top for resting upon a wooden frame, which supported it. Water being poured into this stone vessel, passed through with tolerable facility, and collecting at the point of the oval, fell into a vessel placed below to receive it. The solid impurities in the water being larger than the pores of the stone, were retained, and could be cleared out as often as it was found desirable. About the middle of the last century, a lias was found in Picardy, which acted as a very good filter. Stones of this kind were arranged so as to form a false bottom to a cistern, and the filtered water was drawn off by a stop-cock inserted in the space between the false bottom and the real bottom. One end of a vent-pipe entered this chamber, the other end passing above the cistern, thereby allowing the water to flow freely when the tap was turned.

In 1791, Mr. James Peacock patented a method for filtering by descent or ascent through sand and gravel. The apparatus consisted of a large supply-cistern placed at the proper height, below which was a closed box filled with washed sand and gravel, or with a mixture of charcoal and powdered calcareous stone. The water in the upper reservoir descended by a pipe into the bottom of the box, and the water was filtered by ascending through the strata of sand, &c., and was drawn off by a pipe fixed to the upper part of the box. The filter was occasionally cleaned by means of an exhausting and condensing pump, by which water was rapidly sucked up through the sand and gravel, and forced down again in the contrary direction, by which means the mud and dirt were first thoroughly stirred up, and then washed out of the filter.

In 1812, M. Paul of Geneva invented a filter consisting of a number of metal cylinders, each about 2 feet in length, and about 6 inches in diameter. From twelve to twenty cylinders are employed if necessary for one filter. They are filled to a certain depth with sand resting upon a diaphragm perforated with small holes. The water, which descends from the cistern or reservoir by a pipe, enters the first cylinder, passes through it by a pipe into the second, whence it ascends by another pipe into the third cylinder, and so on until it issues from the last cylinder perfectly filtered.

In 1814, M. Ducommon contrived a filter, composed, 1, of a solid base pierced with holes, for the purpose of supporting the filtering materials; upon this was placed, 2, a layer of sand too coarse to pass through the holes; 3, a second layer of sand of medium size, not sufficiently fine to pass between the interstices of the first layer; 4, a third layer of fine sand, or of pounded freestone, not sufficiently fine to pass through the medium sand; 5, a layer of fine charcoal about ¼ inch thick, if river-water is to be filtered; or a layer of coarse charcoal 10 or 12 inches thick, if foul water is to be filtered; 6, upon this is placed a layer of fine sand similar to No. 3, to keep the charcoal in its place, and protect it; then followed 7, a layer of coarser sand; 8, a still coarser layer similar to No. 2; and 9, a cover perforated with holes to prevent the stream of water from displacing the materials on entering the filter. A filter of this kind, of the sectional area of 40 square inches, was said to be capable of filtering from 110 to 115 gallons of water per hour. The precaution, however, was taken of first straining the water through a piece of canvass as it entered the filter.

In 1815, Count Réal obtained a filtering force by means of the pressure of a column of water, for which a force-pump was substituted by another inventor.

In 1819, M. Hoffmann of Leipsic employed condensed air as the filtering force. This was again improved on by Dr. Rommerhausen, who so arranged his filter, that the pressure of the atmosphere should take the place of the column of water, and of the condensed air. For this purpose the vessel containing the filtered liquid was connected with an exhausting-syringe or air-pump, so that the air could be extracted from it. Across this vessel the filtering materials were arranged in the form of a diaphragm, above which was another vessel containing the liquid to be filtered. It is evident that on rarefying the air in the lower vessel, the pressure of the air on the liquid in the upper vessel would act just as in the old air-pump experiment, in which mercury is forced through the pores of a piece of wood into a vessel contained within an exhausted receiver.

M. Fonvielle's filters also depend on the pressure of a column of water. The filtering materials are arranged in layers, and arrangements are made for cleansing them when required, by the simultaneous action of numerous currents of water, which, under a considerable head pressure, penetrate the mass of the filter in different directions, and from various heights, so that as the water flows in one direction from the filter, the mud and saline matters are removed, and by reversing the action of the stream, the water is perfectly pure and limpid, exciting the greatest surprise in the spectators. This plan is admitted to be founded on that of Mr. Thom already noticed.

In 1831, M. Lelogé contrived an ascending filter, consisting of four unequal parts, placed one above the other, the upper part, containing the water to be

filtered, being equal in dimensions to the other three. The bottom of the filter is of solid stone or earthenware, just above which is an orifice, from which proceeds a tube up to the reservoir of water above. This lowest compartment is of small height; the water on entering it deposits its grosser impurities, which can, from time to time, be removed by a plug provided for the purpose. Above this are two reservoirs, the lower of which is separated from the one below and the one above it by flat perforated stones; this compartment is filled with charcoal; the second compartment is separated from the third by a filtering-stone. According to this arrangement, the water, on being poured into the top of the filter, is strained through a piece of sponge; it then passes down the tube into the bottom reservoir, where it deposits its coarsest impurities; after this, in consequence of the pressure exerted upon it by the liquid column, it filters *per ascensum* up into the third reservoir from the bottom, whence it may be drawn off for use. A filter of this kind exhibited at the Great Exhibition, is shown in Fig. 918, in which *c* is the channel for conducting the water W down into A; it then filters up through B into C, and may be drawn off at *t*. By opening the tap at *h*, the accumulated impurities may be cleaned out.

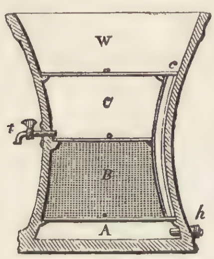


Fig. 918.

We have arranged these contrivances in chronological order, for the purpose of showing who really were the first inventors. Many new patents have been granted of late years for very old contrivances. Examples of domestic filters might be multiplied to almost any extent; but we will close this portion of our subject with a short notice of the filters shown in the Great Exhibition, most of which continued, during the six months that it was open, to supply the crowded assemblies with an abundance of bright sparkling water.

Of late years, that clean and beautiful material, slate, has been much used for water-cisterns. There were five exhibitors of such cisterns, some of which were of large size, and all were furnished with self-acting filters. The following figures show the arrangement of the filters exhibited by Mr. T. Sterling, sen.

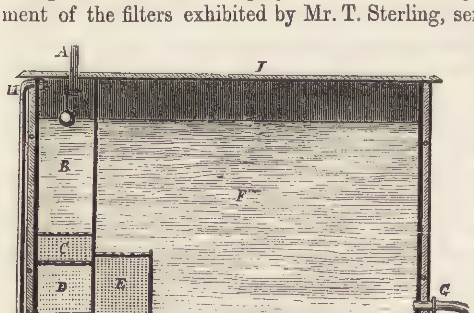


Fig. 919.

Fig. 919 is a section of a large self-supplying filter. A is a pipe furnished with a ball-cock, through which the water to be filtered flows from the main, or other reservoir, into B, the foul-water compartment of the cistern, from which the water, passing down through the filtering media, C, D, and E, consisting of sand and vitrified limestone, rises into F, the pure-water compartment of the cistern, freed from its mechanical impurities. The filtered water is drawn off at G; pipes may also be attached to F, for supplying the kitchen boiler, and other parts of the house. H is a waste-pipe, to carry off the surplus water, in case the action of the ball-cock should be defective. I is a cover to the whole cistern. Fig. 920 is a section of the movable domestic filter, on the same principle, the same letters being used in both cases. It should also be stated, that some of these filters are so constructed as to allow of a hair-brush, such as is used for cleaning bottles, being introduced into a chamber at the bottom, when, by reversing the current of water, the bottom of the filter-bed may be cleared of mud in a few minutes.

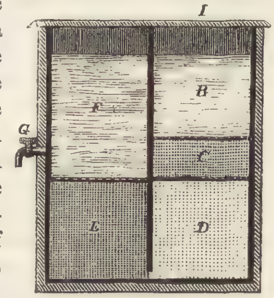


Fig. 920.

Mr. Beart, of Godmanchester, exhibited an apparatus for cutting thin plates of sandstone, or other stone, and also a sandstone filter, containing 5,000 superficial inches of sawn surface.

An elegant little sandstone filter, acting by the pressure of a column of water, was exhibited in the main western avenue, so arranged as to form a fountain of filtered water. In the usual form of this filter, a hollow or porous stone filtering vessel, made in two or more parts cemented together, is placed in the cistern of water to be clarified. This stone is surrounded on all sides at a convenient distance with jackets of perforated zinc, galvanized iron, or wire-work. This jacket consists of two surfaces, the space between them being filled with animal charcoal. The stone vessel is provided with a tap and pipe for drawing off the filtered water. This arrangement is patented by Mr. W. Laird.

An ingenious form of filter was exhibited by the Wenham Lake Ice Company, the invention of Mr. Alfred Bird, consisting of a syphon, the extremity of the short limb of which is furnished with a box containing the filter, so that on inserting this into a cistern or water-butt, and withdrawing the air by applying the mouth to the

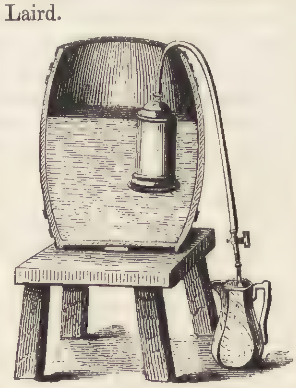


Fig. 921.

extremity of the longer limb, a stream of filtered water can be obtained, which may be arrested or set going by opening or closing a cock at the end.

Another ingenious filter, exhibited by Mr. Murray, consisted of a cock, such as is used for drawing off water from cisterns, with the filtering material packed into the cylindrical portion of the same. It is shown complete in Fig. 922, Fig. 923 being a longitudinal section thereof. It consists of a perforated metal tube, (copper is preferred,) covered with several layers of flannel *f f*, and calico *c c*. The ends of the perforated tube are inserted in metal rings *r r*, and the extremities of the calico are secured round the rings at *s s*, forming a water-tight fastening. The filtering medium is therefore flannel and calico, which, as before stated, is liable to the objections attaching to organic filtering materials: (if asbestos cloth were used, this invention would be perfect.) But as the present contrivance is ingenious, we will give Mr. Murray's description, as communicated by him to the *Mechanic's Magazine*. The metal rings are partly covered with a conical leather washer *l l*, which also ensures a water-tight joint between the dirty and the filtered water. This simple arrangement, enclosed in the outer case D D, forms the whole apparatus. The method of applying it consists in attaching it to the service-pipe *a*, between the cistern and the water-tap A; thus bringing the

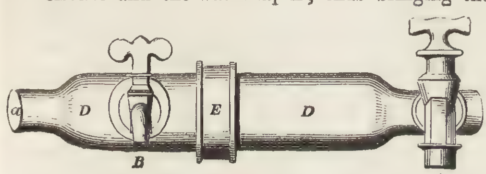


Fig. 922.

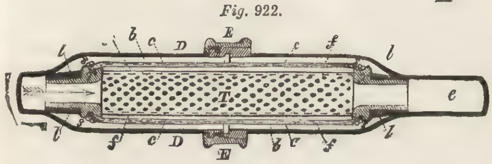


Fig. 923.

pressure of the column of water from the cistern into use. In Fig. 923 this outer case is shown in halves, the one being attached to the service-pipe *a* from the cistern, the other having a short service-pipe *e* fitted with the tap A. The filtering tubes are put into one half, and the other part is brought up and screwed on as at E, Fig. 922. The water, flowing in the direction of the arrow, percolates through the flannel and calico into the space *b b*, whence it is drawn off filtered by the lesser tap B; and the water for household purposes is drawn from the larger tap A after having rushed through the tube T, the filter being thereby cleansed from impurities every time water is drawn from the tap A.

In is remarkable that very few filters were exhibited in the Foreign Department of the Great Exhibition. France contributed three; two of which were of stone, and one of charcoal. Sir W. T. Denison exhibited an excellent filter, made of a dripstone from Norfolk Island. The rock from which this stone was obtained appears to be a raised beach

of calcareous grit. Such filters are much used in Van Diemen's Land.

In conclusion, we may remark, that in the laboratory, unsized paper is almost exclusively used as a filtering material. Other substances, such as flannel, tow, sand, pulverized glass, flints, porous stones, &c. may occasionally be used, but their use is exceptional. In the ninth section of Faraday's "Chemical Manipulation," ample directions respecting paper filters are given. Fig. 924 shows a common arrangement for filtering on a small scale, with filtering paper contained in and supported by a glass funnel. An arrangement is also made for retaining the liquid in the filter at the same height, until the whole of the liquor to be filtered is expended. For this purpose the liquor to be filtered is contained in a flask, inverted, with the neck dipping into the liquor already in the filter; as the liquor passes through and the neck of the flask becomes uncovered, a bubble or two of air enters, more liquor flows out until the neck becomes again covered, and all communication with the air is again cut off.

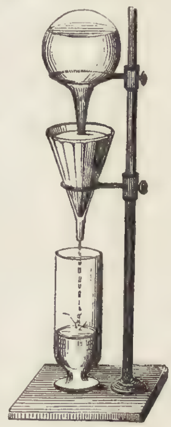


Fig. 924.

Special examples of filtering will be described under separate heads. See SUGAR.

FIRE. This word is of somewhat extensive signification, and is used in various ways, but it commonly refers to an active natural process attended with the emission of heat and light, and also with the decomposition of certain substances which are said to be *burning*, or in a state of *combustion*, during the process, and are said to be *burnt* after the termination of the process. For the nature of the changes which take place we must refer to CARBON—HEAT—OXYGEN: and, for the various applications of fire, to the whole range of the useful arts; for without fire they could not exist, and without an instinctive knowledge of its use, man would scarcely be superior to the lower animals; in some respects he would be their inferior.

FIRE-ARMS. See GUN.

FIRE-DAMP. See COAL.

FIRE-ENGINE, FIRE-ESCAPE, and FIRE-PROOFING. See the next article.

FIRES, CASUALTIES BY, EXTINCTION AND PREVENTION OF. A large city, like London, containing 300,000 houses, is necessarily liable to many casualties from fire. In the construction of these houses much timber and other inflammable materials are used; the furniture is also, for the most part, ...able of easy ignition: our system of warming lea... use of a fire in many rooms, and often in ev... of the house; our system of artificial il... involves the use of gas, lamps, and candl... vient to which are lucifer-matches, capabl... not of spontaneous ignition; many sho... considerable stores of spirit. turpentine,

and even of gunpowder; dangerous trades are permitted, or are not forbidden, in crowded districts; so that with these, and many other causes of danger, the safety of all the inmates of a house may depend, not only upon the care of each individual in it, but also upon the care of his neighbours. In the multifarious operations of a household, of a shop, or of a wareroom, in which fire is so largely concerned as a source of light, of warmth, or of heat, much vigilance is required to restrain within due bounds the operations of that wonderful agent which is truly described as "a good servant, but a bad master." During the day, when people are engaged in their accustomed duties, there is but little danger to be anticipated from fire; it is at night, when care and vigilance are slumbering, that the dread element, ceasing to serve and not expiring, often becomes the imperious master. There are probably few inhabitants of London who have not realized the startling effect of the cry of *fire* breaking in upon the silence of night. Taken up from mouth to mouth, we hear it in the distance in living echoes, accompanied by the quick tread of those who are hastening to the scene of danger and excitement. There is a momentary lull, in which neither cry nor tramp of feet is heard, but soon we perceive a sound like that of rolling thunder, becoming louder and louder every moment. We look out, and see the fire-engine swiftly passing by, drawn by horses at full gallop, heeding not the luckless passenger, and giving no quarter to other vehicles. Men, and horses, and vehicles, all yield to the fire-engine, which is soon beyond our sight and hearing. On proceeding into the street, the red glow of the sky immediately points out the direction of the fire: we join in the general excitement and hurry forward to the scene. A few minutes' quick walking will apparently bring us up to it; we hurry on, but reach it not; the red glow in the sky is stationary, but the streets between it and us seem to expand in length, and at every step to increase, instead of diminishing the distance: the red glow in the sky contrasts strangely with the pale yellow of the gas-lamps. "Where is the fire?" One says one place; another, another more distant; a third names a spot still more distant. But at length we near it. The streets are crowded with people, the road is wet with mud, the gutters are overflowing with water—a regular succession of dead, hollow, determined blows shows that the engine is being worked by willing arms—a jet of water rises up in a crystal line brilliantly illuminated by the flames which are streaming up out of the windows. With some exertion, and with feet drenched with thin mud, we get as near as we are allowed by the police, who are keeping a clear space for the engines and the firemen. We get near enough to feel the intensity of the heat, and to witness its effects in cracking the window-panes of the opposite houses, and blistering the paint on the doors. Every window, every roof, is alive with spectators; some of the neighbours are getting out their furniture; others are running about distracted; a third group are seated on the pavement, stricken with terror. Contradictory accounts are circulated respecting the origin of the fire and the present condition of the occupants of the devoted house. One report (probably the true one) is, that they are all safely housed with a neighbour; another report is, that three persons are missing. But the din increases: other engines having arrived, are now at work in front and in the rear. The war between the two elements is continued for an hour or more, till at length fire yields to water: the flames no longer discharge their rolling volumes of black smoke into the air, nor light up the sky with unaccustomed splendour. Dense volumes of steam arising from the evaporation of the water are the first signal that the fire is over; the multitude begins to break up, and soon the house on fire is nothing more than a wreck of blackened timbers and hollow walls.

The intense interest which a house on fire excites in the population of London, does not arise merely from curiosity and love of excitement. We believe, that in that vast concourse of people there is not an individual who would not work at the engines for hours without fee or reward, and although the fire-offices pay 1*s*. an hour for such labour, it is generally refused, or is expended in beer. Curiosity and love of excitement are doubtless great motors in bringing together this large assembly; but there are higher elements at work. A London fire is a grand and impressive spectacle, accompanied by a sufficient sense of danger to impart to it an excitement in which every one feels a personal interest; for the fire, which in this distant part of the town may have deprived a fellow-creature of his life, as it certainly has deprived several families of a home, and perhaps of the whole of their worldly goods, may some other night visit my neighbour's house or my own, and involve me and those who are dear to me in similar ruin. The motives, therefore, which excite this deep interest in a fire are of a very composite character: curiosity—love of excitement—feelings of humanity—interest in the safety and welfare of our fellow-creatures, no less than admiration of the skill and courage of that noble brigade whose business it is to be ready at any hour of the day or night with their own services, and the means placed at their disposal, for the extinction of fires in the metropolis and its vicinity.

That an organized staff of men, trained and accustomed to this duty, is required, will be evident from the statistics of the London fires. From the year 1832, when the London Fire Brigade was organized, a very accurate register of the metropolitan fires has been kept. The following extracts from the Register for the years 1833 to 1848 will show the kind of houses and occupations which are most exposed to casualties from fire:—

Apothecaries, and dealers in drugs	36
Bakers	244
Booksellers, Binders, and Stationers	137

Of these, 96 burnt gas, and the fires caused by gas amounted to 28.

Cabinet-makers	156
Carpenters and workers in wood	434

The accumulation of shavings, and their use in the stove, or in heating the glue-pot, account for the large proportion of fires in these trades.

Churches 33

Of this number 3 were totally destroyed, 10 much damaged, the remainder only slightly. 8 of these fires arose from stoves and over-heated flues; 2 from lightning.

Drapers, woollen and linen 254

239 of these burnt gas, and 140 cases arose from accidents with, or careless management of gas; 105 cases were very severe.

Fire Preventive Company 1

This arose from an experiment with a *fireproof plaster*, which took fire, burnt furiously, and caused much damage. Where was the scientific chemist which the Company did employ, or ought to have employed?

Firework-makers 49

Much damage was done in all these cases, which originated in the nature of the materials used in the trade; and these were in some cases ignited by the men smoking tobacco, by boys playing with fire, or from a squib or cracker being thrown into the shop-window "for a lark."

Gas-works 37

These are always supervised by scientific men, who adopt many precautions, and have means of prevention at hand: hence of these cases only 9 were much injured, and none totally destroyed.

Grocers 120

Of these, 109 burnt gas, and 26 of the fires arose from carelessness therewith.

Gunpowder-sellers 1

Knowing the danger, care is taken, and there is only 1 fire in 16 years.

Lodgings 868

Of these, 368 were caused by the taking fire of curtains, linen airing, &c.; some were caused by searching for vermin.

Lucifer-match makers 101

Lunatic Asylums 2

In the one case, familiarity with danger induces carelessness on the part of the operatives: in the other, persons who ought not to be trusted with fire are not trusted.

Printers and Engravers 72

Private houses 3,352

Of this number 1,302 originated in the taking fire of curtains, dresses, airing linen, &c.

Sale-shops and offices 526

Of these, 379 consumed gas; and the fires from this source were 129.

Ships 82

Caused by stores, flues, cooking, igniting of cargo, smoking tobacco, &c.

Stables 192

Caused by candles, lucifers, smoking tobacco, intoxication, &c.

Tailors 81

Of this number 17 were caused by gas, 13 by candles, and some by smoking tobacco.

Theatres 20

Of this number 8 arose from gas; others by smoking tobacco, and the taking fire of curtains, dresses, &c.

Tobacconists 43

6 of these fires were caused by gas; 6 by lucifer-matches; others by curtains catching fire; one was caused by a cat, and another by rats gnawing a box of lucifer-matches, which took fire under the friction of the teeth. A cat is not an unfrequent cause of fire, either by upsetting the clothes-horse with things airing, or, by creeping under the clothes to get nearer the fire, and so dragging some of them on her back into the kitchen fender.

Victuallers 542

Of this number 21 houses were totally destroyed; 167 much damaged, and 354 damaged slightly. 83 arose from flues; 73 from curtains, dresses, &c. taking fire; 65 from gas; 36 from smoking tobacco; 35 from accidents with a candle. The remainder arose from lucifers, hot cinders, a spark, intoxication, children playing with the fire, a monkey ditto.

The number of fires, and alarms of fire, that occurred during the fifteen years ending in 1847, present a continual increase. In 1833 they amounted to 458; in 1834, to 482; and so on down to 1847, when they amounted to 836. The total number of fires during the fifteen years was 9,662, making an average of 644. In 1848, the number of fires amounted to 805, showing in this case (which is an exceptional one) a decrease in the previous year of 31. In 1849 the number amounted to 838, being an increase of 33 over the previous year. In 1850 it was 868, being an increase of 30 over the previous year. This increase in the annual average number of fires, notwithstanding the efficiency of the Fire Brigade, must be referred to the rapid increase in the number of houses, and the increased use of gas and lucifer-matches.

The following tabulated statement respecting the fires of 1850 is copied from Mr. Baddeley's paper, in the *Mechanic's Magazine*, on the London Fires in 1850:[1]—

Months.	Number of Fires.	Fatal Fires.	Lives lost.	Chimneys on Fire.	False Alarms.
January ...	80	2	2	10	10
February .	79	0	0	5	6
March	84	2	2	12	9
April	69	3	3	5	10
May	56	2	2	2	2
June	72	3	4	4	4
July.........	62	0	0	6	4
August ...	66	0	0	9	8
September	67	1	1	7	12
October ...	82	1	1	7	9
November	85	1	1	5	9
December.	66	2	2	7	8
TOTAL	868	17	18	79	91

(1) The Editor gladly takes this opportunity of bearing his testimony to the value of Mr. Baddeley's contributions to the *Mechanic's Magazine*, for many years past, on the subject of fires, their statistics, means of extinction, prevention, &c. It is no mean honour to be a competent authority on any subject; and Mr. Baddeley is such on this very important one.

Instances in which insurances were known to have been effected upon the building and its contents . .	381
On the building only	141
On the contents only	77
No insurance	269
	868
Alarms from chimneys on fire . .	79
False alarms	91
Making the total number of calls .	1,038

Out of the 868 fires, 267 were extinguished by the prompt exertions of the inmates; 389 were extinguished by the inmates, with casual voluntary aid; while the suppression of 212 devolved on the firemen.

The Fire Brigade is supported by the various Insurance Offices of the metropolis, whose interest it evidently is to afford the most powerful and efficient assistance, not only in all those cases in which they have undertaken to make good the damage to a certain insured amount, but in those houses also which are uninsured, for if these were neglected they might involve the destruction of a whole neighbourhood, insured and uninsured alike. It should, however, be remarked that the firemen are entitled to the rewards of 30*s*., 20*s*. and 10*s*., for the first three engines that arrive, to be paid either by the owner of the house at which the accident happens, or by the parish.

The Brigade is divided into 4 sections, with 19 stations, in the most central quarters of the metropolis, including two floating engines on the Thames. The process of getting the Brigade into activity is described in a spirited article contained in the first volume of Dickens's *Household Words*, from which we gather a few particulars. When a fire breaks out, a policeman springs his rattle, and hurries off to the nearest fire-brigade station, giving information as he passes along to his comrades, one of whom proceeds to the fire-brigade station next beyond, while others fetch the fire-escape which is provided in every parish by the "Royal Society for the Protection of Life from Fire." The fire-engine kept by the parish is also sent for. On arriving at the chief office, the policeman rings the night-bell, which is immediately answered by the fireman on duty for the night; he inquires after the locality, and a few short particulars respecting the fire; he then pulls a bell-handle, and applying his ear to the mouth-piece of a speaking pipe, soon hears the voice of one who is accustomed to be disturbed at night; it is that of the superintendent (at the city station, Mr. Braidwood himself), who answers from his bed, and on learning the particulars by means of the speaking-pipe, gives the necessary orders, immediately gets up, and in three minutes is descending the stairs attired in the thick cloth frock-coat, boots and helmet of the Fire Brigade. The men below act with equal promptitude. No sooner is the superintendent roused than the watchman rings the foreman's bell, the engineer's bell, and the single men's bell, the latter to call up 4 unmarried men. He then runs to the stables, calls up the charioteer by the way, and 2 other firemen lodging close by, and then returns to assist in getting out the horses. By the time the superintendent has buttoned the last button he has arrived at the bottom of the stairs, and finds the engine ready and in working order, with its usual furniture, implements, and tools, placed within or packed about it, and of which the following is an inventory:—Short scaling-ladders made to fit into each other attached to the sides; 6 lengths of hose, branch pipes, director pipes, spare nozzle, suction pipes, a goose-neck for delivering water into the engine, iron wrenches called dog's-tails, a canvass sheet with rope handles round the edge for the purpose of catching people who are bold enough to jump out of the window, which they may do with perfect safety when the sheet is held by firemen; a dam-board for arresting the water and giving it depth, a portable cistern, strips of sheep-skin for mending bursting hose, balls of cord, a flat rose, an escape chain, escape ropes, a mattock, saw, shovel, poleaxe, boat-hook, an enormous crow-bar to burst in through doors or walls, or to break up the pavement, keys for opening fire-plugs or turning stop-cocks of the water mains. The superintendent mounts the engine to the right of the driver; the engineer, foreman and firemen mount also, and range themselves on each side of the long red chest at the top, which contains most of the articles above enumerated. Well acquainted with all the streets, and almost with all the houses of London, the superintendent directs the driver by the very shortest way, and having arrived at the scene of operation, he sees exactly all that has happened, all that must happen, that may happen, and all that may be prevented. The nature of the combustible, the direction of the wind, the age of the houses, the presence or absence of party walls; these and many other local particulars are rapidly generalized, a sound conclusion is at once arrived at, and a plan of operations decided on. Having ascertained that all the inmates are safe out, he orders 3 of the engines, which have now arrived from other parts, to continue their efforts; his own engine, and perhaps another, are driven round to the other side in order to attack the enemy front and rear. The water-plugs are drawn, the gutters flooded, the gully-hole is covered over, and a dam-board placed so as to arrest the stream, the portable cistern is filled, and the suction-pipes of the engine placed in it. Hundreds of volunteers are ready to work the engines: 20 pair of hands, 10 on each side, are required for each engine, and such is the ardour of the pumpers, and such the wasteful expenditure of useful muscular force, that the engine is frequently crippled before it has done 5 minutes work. Two firemen are sent into the house, no fireman ever being allowed to enter alone; two others enter below, and a lengthened hose is handed up to them with a boat-hook through the front drawing-room window, supposing the fire to have originated in the upper part of the house. A fireman ascends to the room where the inmates were last seen; it is full of smoke, but on dropping down and creeping

along with his face almost touching the floor, he gets 10 or 12 inches of clear space, and air fit for respiration. Many a person who has fallen down fainting with the heat and suffocated by the smoke, is thus discovered and dragged out by the brave firemen, is handed to a comrade on the stairs, conveyed out into the open air and recovered. In this way, also, the fireman actually gets within 10 or 12 feet of the fire, and can direct the jet of water upon it, dashing it out, leaving a blackened, scorched mass behind, and raising clouds of steam.[1]

The men are on the watch to see that the retreat is not cut off; a chain attached to the balcony of the drawing-room secures escape in case of need. All the efforts of the firemen are first directed to save life; this being done, furniture is secured; if the danger presses, the furniture is disregarded, however costly; all efforts are made to prevent the fire from extending to the adjoining houses. It is not till the molten lead is pouring down from the roof, and the ceilings are falling, that the men descend by the iron chain. Drenched and nearly exhausted, they are received by the superintendent and two men below, and are sent to change their clothes and get refreshment. At length the fire is subdued; a couple of men are left to watch the ruins, which are next day carefully examined by the superintendent, who is thus able, in many cases, to detect the cause of the fire, and to recover property buried under the ruins. What is remarkable in all these proceedings. is the smallness of the force employed. In a continental city, a regiment of soldiers would probably be employed in putting out a fire and preserving the peace: in London the whole affair is managed by a few policemen, a few firemen, a crowd of willing volunteers, and a multitude of spectators, most of whom would do their best to keep the peace and assist the efforts of the authorities.

Mr. Braidwood, in his work on Fire-Engines,[2] states that the operatives in certain trades make better firemen than in others; for example, he found that *slaters* make the best firemen, probably from their being accustomed to climbing and going along roofs; *house-carpenters* also make good firemen, from their acquaintance with the construction of buildings, which lead them to know where danger is to be apprehended, and, from the appearance of the house, where the staircase is situated, and how the house is divided; *plumbers* are also good, from being well accustomed to climbing, and are also useful in working fire-cocks, covering the eyes of drains with lead, and generally in the management of water; *smiths* are also to be recommended, as they can perform any repair about the engine, &c. Plumbers and smiths are also better able to bear the heat and the smoke than most other men; but the operatives in all the above-mentioned trades are better able than in most others to endure the extremities of heat and cold, wet and fatigue. If the men are selected between the ages of 17 and 25, they are more easily trained than older men.

We now come to consider the mechanical means which are adopted: *first*, for the extinction of fires; *secondly*, for the preservation of life and property during fires; and, *thirdly*, for the prevention of fires.

The Fire Engine is undoubtedly the most efficient instrument which has hitherto been employed in the extinction of fires. Beckmann in his "History of Inventions," has a learned essay on the origin of this most useful engine. He shows, by quotations from the ancient writers, that the Romans had some contrivance termed *sypho*, for extinguishing fires, but no description thereof has been given. In the building-accounts of the city of Augsburg, bearing date about the year 1518, "instruments for fires," "water syringes, useful at fires," are mentioned. In 1657 Caspar Schott describes a fire-engine at Nuremburg, which appears greatly to have resembled the modern engine. It was drawn by 2 horses on a sledge 10 feet long and 4 feet broad; the water cistern was 8 feet in length, 4 in height, and 2 in width; it was moved by 28 men, and forced a stream of water, an inch in diameter, to the height of 80 feet. Schott does not refer to it as a new invention, but states, that 40 years before, *i. e.* in 1617, he had seen a similar one, but much smaller, in his native city Königshofen. These engines were, however, very imperfect; "they had neither an air chamber nor buckets, and required a great many men to work them; they consisted merely of a sucking-pump and forcing-pump united, which projected the water only in spirts and with continual interruption. Such machines, on each movement of the lever, experience a stoppage, during which no water is thrown out, and, because the pipe is fixed, it cannot carry water to remote places, though it may reach a fire at no great distance, where there are doors and windows to afford it a passage. At the same time the workmen are exposed to danger from the falling of the houses on fire, and must remove from them to a greater distance. Hautsch, the maker of the above engine, had adapted to it a flexible pipe, which could be turned to any side as was necessary, but certainly not an air-chamber, otherwise Schott would have mentioned it. In the time of Belidor, there were no other engines in France, and the same kind alone were used in England in 1760. Professor Busch at least concludes so, from the account then given by Ferguson, who called Newsham's engine, which threw the water out in a continued stream, a new invention."

(1) Mr. Baddeley remarks, that "the only successful mode of using a fire-engine, is to take the director or branch-pipe into the building, as near as possible to the fire, and be sure that the stream of water strikes directly upon the burning materials. This cannot be too often or too anxiously inculcated on every person using a fire-engine. Every other method not having this for its fundamental principle, will, in nine cases out of ten, utterly fail. When the water is thrown into the building hap-hazard from the street, it is impossible to say if any of it touches the parts on fire, or not, unless the flames appear at the windows." In order to economise the water, Mr. Baddeley has invented a *spreader* to be attached to the jet, the object of which is, to throw the water in such a way that the entire surface of the burning part may be wetted and extinguished, and no more water used than is required.

(2) "On the Construction of Fire-Engines and Apparatus; the Training of Firemen, and the Method of Proceeding in cases of Fire," by James Braidwood. Edinburgh, 1830.

The inventor of the air-chamber, the most important characteristic of a fire-engine, is not known. In a work published by Perrault in 1684, an engine belonging to the Royal Library at Paris is mentioned as consisting of only one cylinder, and yet throwing out water in one continued jet to a great height. In Germany, Leupold manufactured and sold a number of fire-engines furnished with air-chambers, the construction of which he kept secret for some time, but published an account thereof in 1720.

The invention of the leathern hose was also a great improvement; by means of this hose, which was capable of being lengthened or shortened at pleasure, water could be supplied to the engine from a distance, thus rendering the laborious conveyance of water by buckets unnecessary; the extremity of this pipe which dipped into the water, was furnished with a metal strainer pierced with holes to prevent the admission of dirt, and kept suspended above the mud by a piece of cork. By means of the hose the fire-pipe also could be properly adjusted. This invention belongs to two Dutchmen, named Van der Heide, who about 1670 were inspectors of the apparatus for extinguishing fires at Amsterdam. In 1690 they published a folio volume containing some valuable engravings, "the first seven of which represent dangerous conflagrations at which the old engines were used, but produced very little effect. One of them is the fire which took place in the Stadthouse of Amsterdam in the year 1652. The 12 following plates represent fires which were extinguished by the new engines, and exhibit at the same time the various ways in which the engines may be employed with advantage. According to an annexed calculation, the city of Amsterdam lost by 10 fires, when the old apparatus was in use, 1,024,130 florins, but in the following 5 years, after the introduction of the new engines, the loss occasioned by 40 fires amounted to only 18,355 florins, so that the yearly saving was 98 per cent."

The English were very slow in availing themselves of the discoveries of the German and Dutch engineers. At the close of the 16th century, *hand squirts* were in use for extinguishing fires; they were made of brass, of the capacity of from 2 to 4 quarts. A syringe capable of discharging two quarts of water, was about 2½ feet long and 1½ inch in diameter, that of the nozzle being half an inch. Every syringe required 3 men to work it; one man on each side grasped one of the two handles of the instrument with one hand and the nozzle with the other, while a third man worked the piston or plunger. In filling it the nozzle was immersed in water and the piston drawn out; the bearers then elevated it and directed the nozzle towards the fire, while the third man pushed in the plunger. Several of these instruments are still preserved in the vestry-room of St. Dionis Backchurch in Fenchurch-street, London. They were improved by being fixed in a portable cistern, and furnished with levers for working the piston; but in their best form they were inefficient contrivances, and had very little influence in checking the extensive fires which were so common at and previous to this time in large cities, when houses were built with abundance of timber, and instead of party walls, mere lath-and-plaster partitions, thus making a whole block of buildings like one house, and entailing the destruction of a whole neighbourhood by fire, instead of the single house in which the fire originated.

The principle of the fire-engine will be understood from the section, Fig. 925, in which H is the pipe or hose, which is extended by means of screw-joints to the plug or cistern, whence the supply of water is obtained. This pipe H communicates with two valves V V, which open into the pump barrels of two forcing-pumps A A, containing solid pistons *p p*. The piston-rods of these are connected with a working-beam, so arranged as to be worked by a number of persons on each side. From the sides of the pump-barrels above the valves V V, proceed force-pipes, which communicate with an air-chamber C by means of valves V′ V′ opening upwards into it. Through the top of the air-chamber passes a pipe *e* down nearly to the bottom. To the upper part of this pipe is attached the hose or jet used for directing a stream of water on the fire. This arrangement being understood, the action of the engine will be apparent. By the alternate motion of the pistons *p p*, water is drawn through the valves V V, and propelled through the forcing-valves V′ V′. Or to confine our attention for a moment to one of the pumps: on raising the piston *p* in the direction of the arrow, the valve V opens, water rushes into the cylinder A by the hose H, following the piston *p* as high as it ascends. On depressing this piston, the valve V closes, thus preventing the water from returning into H by way of V. As the water must escape somewhere from the downward force of the piston, it acts first upon the point of least resistance, which is the valve V′ opening upwards. The water forces this open, and rushes into the air-chamber C. The piston being then at the bottom of the cylinder, again commences its ascent, during which the valve V′ closes, the valve V opens, and water rushes into the cylinder as before. It is obvious, that as one piston is ascending while the other is descending, a continuous action is thus kept up, and water is always being forced into the air-chamber through one of the two valves V.′ Now it is evident that directly the water rises above the lower mouth of the pipe *e*, the air in the air-chamber is completely shut in, and just in proportion as the water accumulates, the enclosed air is compressed; the effect of this is, that the air in the air-chamber acts as a spring under constant

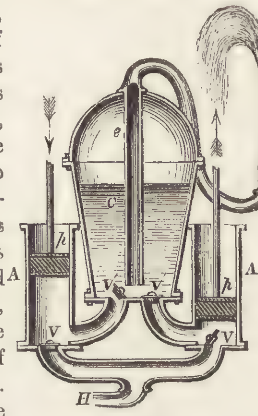


Fig. 925.

compression. Its elastic force being exerted on the surface of the water, forces a column of water into the pipe *e*, and out through the hose and jet attached to it, with a force depending partly on the degree of condensation, and partly on the elevation of the extremity of the hose above the level of the engine. The pressure of the condensed air has *first* to support a column of water, whose height is equal to the level of the end of the tube above the level of the water in the air-chamber; and until the pressure of the condensed air exceeds what is necessary for this purpose, no water can spout from the end of the hose; and *secondly*, the force of the jet will be proportional to the excess of the pressure of the condensed air above the weight of the column of water, whose height is equal to the elevation of the end of the hose above the level of the water in the air-vessel. When the air in the air-chamber is condensed into half its bulk at atmospheric pressure, it will act upon the surface of the water with double the atmospheric pressure; while the water in the force-pipe being subject to only one atmospheric pressure, there will be an unresisted upward force equal to one atmosphere, which sustains the column of water in the tube. Consequently a column will be sustained or projected to the height of about 33 feet. When the air is reduced to one-third of its original bulk, the height of the jet will be 66 feet, and so on according to the proportions shown in the following table:—

Height of water in the air-vessel.	Height of the compressed air.	Ratio of the air's elasticity.	Height to which the water will spout.
$\frac{1}{2}$	$\frac{1}{2}$	2	33
$\frac{2}{3}$	$\frac{1}{3}$	3	66
$\frac{3}{4}$	$\frac{1}{4}$	4	99
$\frac{4}{5}$	$\frac{1}{5}$	5	132
$\frac{5}{6}$	$\frac{1}{6}$	6	165
$\frac{6}{7}$	$\frac{1}{7}$	7	198
$\frac{7}{8}$	$\frac{1}{8}$	8	231
$\frac{8}{9}$	$\frac{1}{9}$	9	264
$\frac{9}{10}$	$\frac{1}{10}$	10	297

Fire-engines on the above principle were constructed towards the close of the 17th century in France, Germany, and England. Newsham's engine was patented in England about this time, and continued in use to the year 1832, when the Insurance Offices of London, having combined in forming a general fire-engine establishment, adopted an improved form of engine. Newsham's engine consisted essentially of a strong oak cistern, about three times as long as it was broad, mounted upon four wheels. The pumps and air-vessel were enclosed in a case, from the top of which issued the jet-pipe. The suction-pipe was of strong leather, with a spiral piece of metal running throughout its length to prevent it from collapsing as soon as the air within it became rarefied by the first working of the pump. One extremity of this pipe was screwed to a nozzle at the lower end of the cistern, the other extremity being furnished with a strainer immersed in the water. In cases where the suction-pipe could not be used, water was poured by means of buckets into a wooden trough furnished with a strainer, from whence it passed into the cistern. A three-way cock, situated beneath the hinder trough, was turned according as the water was drawn through the suction-pipe, or was poured in by hand. The piston-rods were connected by chains to a double sector. There were two chains to each piston, one passing from the top of the sector to the lower end of the piston-rod, the other from the top of the piston-rod to the bottom of the sector; the chains were riveted to the sectors, and attached to the piston-rods by screw-nuts. Long handles connected with the sectors could be worked on each side. With such an engine, the water could be thrown in a continuous jet to the height of 60 or 70 feet, and with sufficient velocity to break windows. The engine was successful on its first introduction; it was purchased by the Government, by the nobility and gentry, by the different parishes, and by the insurance companies founded about this time, viz. the Hand-in-Hand, 1696; the Union, 1714; and the London Assurance Company, 1720.

In 1792 an improvement on Newsham's engine was patented by Mr. C. Simpson. In this engine the valves are contained in separate chambers instead of being placed within the cylinder and air-vessels, so that if a valve should fail, it was only necessary to unscrew and remove the covering-plate, when the valve could be got at without disturbing the other parts; whereas, in Newsham's engine, if one such valve became deranged, the whole engine had to be taken apart. Fig. 926 is a sectional view of one of these engines made by Mr. W. J. Tilley of London, such as is recommended by Mr. Braidwood in his work on Fire-Engines. This engine is furnished with 6-inch barrels, and has a 7-inch stroke. The cistern A is of oak, the upper part B, and the side-boxes or pockets of Baltic fir. The sole, D, upon which the barrels stand, and which also contains the valves, is of cast-iron, with covers of the same material screwed down, and the joints made good with leather. At each end of the sole are brass pieces, E, in one of which is the suction-cock F, and to the other is attached the air-vessel G. This is of sheet copper joined at R, and attached to E by a screw. The exit-pipe H is attached to the under side of E by a swivel screw. The valves I are of brass, and ground true, so as to be water-tight. The barrels K are of cast-brass, and the bushes L of the same material. The engine is set on four grasshopper springs M. The hind axle is kneed at the cistern. The handles, *h*, of the levers P, are of lancewood. The box S is used for keeping wrenches, cord, &c. It has a false bottom, and the space T below it is used for keeping the materials necessary for a fire-escape, a chain ladder of 80 feet, a large canvas bag, and two strong belts. The hose is kept in the fore part of the cistern A and the box B. The directors and suction-pipes are carried in the side-boxes or pockets. The rest of the tools required are arranged about the engine. There is also a bar for locking

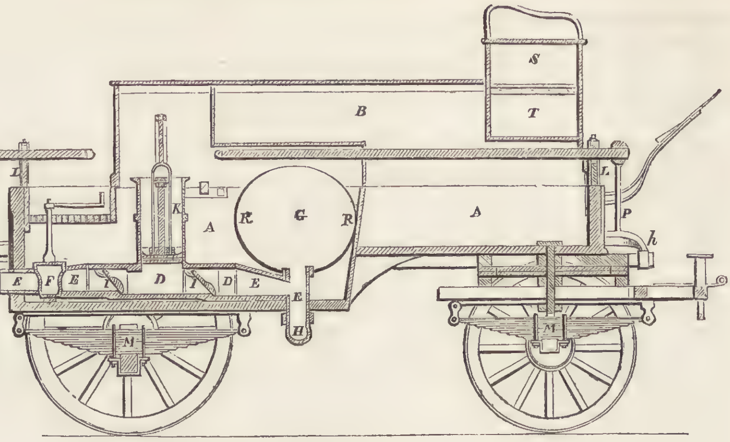


Fig. 927.

Fig. 926. SECTION OF FIRE-ENGINE.

the shafts to prevent them from interfering with the wheels when the engine turns. The director or jet-pipe, Fig. 927, is of copper, with a brass nozzle. The hollow screw at A is made to fit the coupling-joints of the hose. The joint B unscrews at C to allow the jet to be cleaned out. The interior should be polished to diminish the friction, and the orifice protected by being sunk a little within the metal.

The Steam Fire-Engine is an ingenious application by Mr. Braithwaite, of the moving power of steam to the working of fire-engines. The mechanical arrangement consists of two cylinders, the one 7 inches in diameter, which is the steam cylinder, and the other 6½ inches in diameter, which is the water-pump. Both cylinders are in a horizontal position, by which means the parallel motion is easily produced. The boiler is on the construction and principle of Braithwaite and Ericson's patent steam-generator. This engine will deliver about 9,000 gallons an hour to a height of 90 feet through an adjutage of ⅞ inch. The time of getting the machine into action from the moment of igniting the fuel is 18 minutes, the water being cold. As soon as an alarm is given, the fire is kindled, and the bellows attached to the engine are worked by hand. By the time the horses are harnessed in, the fuel is thoroughly ignited, and the bellows are then worked by the motion of the wheels of the engine, so that on arriving at the fire, the steam is ready. The expense of fuel is estimated at 6*d*. per hour.

In 1793, Mr. Joseph Bramah took out a patent for a fire-engine on the vibratory principle. [See PUMP.] This engine was defective in action. It was reproduced by Mr. Rowntree in the modified form, but not very successfully. Mr. John Barton, however, so far improved upon these attempts as to produce a tolerably good working engine, of which a section across one end is represented in Fig. 928. *a* is the cylinder or working-barrel of brass or iron; *b* is the fan or piston forming a radius of the circle, and composed entirely of metal on the expanding principle, with springs and segments as in Barton's metallic pistons. *c c c c* are 4 valves opening upwards; *d* is the air-vessel with the exit orifice at its lower part; *e* is the water-cistern; but this engine can also be supplied from a pond, &c., by means of a hose. "This engine is worked by the elevation and depression of the handles *h h*, connected with the axis of the fan *b*, which vibrates backwards and forwards in the upper part of the cylinder, and delivers at each stroke nearly one-half of its contents. The working of the fan or

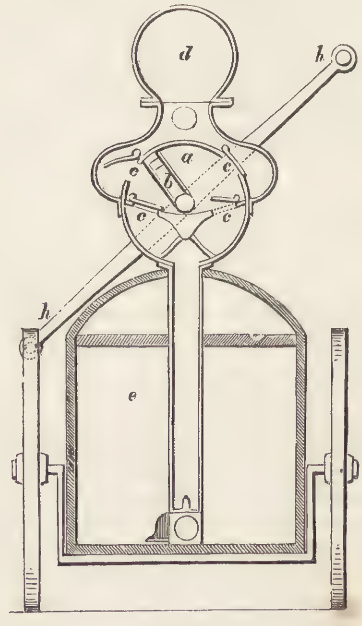


Fig. 928.

piston *b* being air-tight, tends to produce a vacuum below on that side of the cylinder *a* where the handle is elevated, and the pressure of the atmosphere causes the water to rush up into this space. During this stroke, the air that occupied the other side of the cylinder has been partly expelled, and this space, on the second stroke being made, is filled with water, while that already on the other side of the piston is forced up into the air-vessel, and thence through the exit-pipes in a continuous jet."

A new form of engine was patented a few years ago, by Mr. White, of Salford. In this engine a

number of small pumps, or working barrels, is substituted for the large cylinder. Each pump is worked independently of the others, and is constructed of a diameter to suit the power of a single man, so that if only one man is at hand at the commencement of a fire, he can immediately begin to work his portion of the engine, whereas, in working the ordinary form of engine, a considerable number of men is required. In the new engine it is stated that one man can throw water to a height of 160 feet. The pumps are mounted on a circular tank or reservoir, as in Fig. 929, which is a horizontal section of a set of pumps:

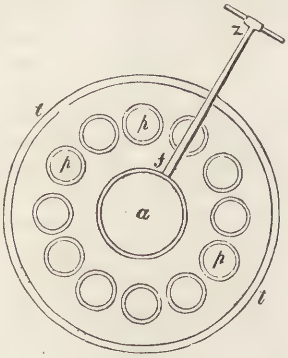


Fig. 929.

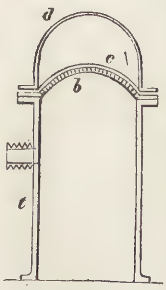


Fig. 930.

t is the tank from which the pumps are supplied; it is mounted upon wheels in the usual manner, for facility of transport. *p p* are the force pumps, 12 in number, each of which is worked by a separate lever *z*, moving upon a fulcrum at *f;* the air-vessel *a* is placed in the centre of the circle of pumps, all of which discharge their water into it. Above the air-vessel is a platform upon which the firemen stand. Fig. 930 is a vertical section of the air-vessel: *t* is the external vessel, on the top of which is a perforated plate *b*, over which is stretched a piece of vulcanized India rubber *c; d* is a hemispherical vessel forming a cover to the various parts, which are well bolted together. Within this last vessel the air is compressed to about two atmospheres, or 30 lbs. on the square inch, as the elastic resisting medium for the water to press against. By this contrivance the water does not come in contact with the air, and is thus prevented from passing off from the air-vessel with a crackling noise so often heard in the working of common fire-engines.

A trial was made with this engine at the Salford Gas-works, in December, 1845. The chimney of the works is 129 feet high; this was selected as the mark to show the height to which Mr. White's engine, and the *Deluge* engine belonging to the Town Council, could throw the water, each being worked by the same number of men. When White's engine was set to work with its full complement of 12 men, it threw the water for a short time several feet above the chimney; when the same number worked the Deluge they could not throw the water half that height, and even when 38 men were employed, they could not make the water reach the top of the chimney. Three lengths of hose pipe, about 120 feet in length, and with a five-eight nozzle, were then attached to each engine, and the result was equally in favour of Mr. White's engine.

Other forms of fire-engine might be noticed, such as Deane's portable engine and watering pump, in which the air-vessel surrounds the barrel of the pump. The centrifugal pump is also applied as a fire-engine; but we must refer the further consideration of these matters to the article PUMP.

Mr. Phillips's *Fire-annihilator* has excited considerable discussion. It is an apparatus arranged for generating a large quantity of gaseous matter, which will not support combustion. A house on fire is to have injected into it a sufficient volume of these non-supporting gases, to displace the air in the building, and to neutralize the effect of the strong currents of air which stream in on all sides upon the burning mass. The materials for generating the non-supporting gases are, equal parts of chlorate of potash, and sugar, ignited when required, by crushing a small glass vessel, containing sulphuric acid. The salt and the sugar, moulded into a homogeneous mass, are placed in a perforated cylinder, contained within a second perforated cylinder, which is contained in a third air-tight cylinder, and the whole is enclosed in an outer casing. Water is contained in the space between the bottom of the third cylinder and the outer casing; this is fitted with a vertical pipe opening into the space between the second and third cylinders, so that, as the metal expands by the application of the heat, water will be forced up the pipe, and mingling with the gas, will saturate it with moisture; the gas will then escape through an opening at the top of the case. We are not aware that this apparatus has ever been used in extinguishing an accidental fire; it has been used at several show fires with a considerable amount of success. It has been suggested that every house should be provided with a small fire annihilator; but, supposing its merits to be admitted, it would be necessary to supply the inmates of most houses with sufficient presence of mind to enable them to use this apparatus with effect; and having presence of mind, they might do without the annihilator; for, as Mr. Baddeley justly remarks, "of the 805 fires in the metropolis during 1848, no less than 577 were extinguished by the exercise of as much presence of mind as would be required to apply Mr. Phillips's apparatus."

Other plans for the extinction of fire might be noticed at considerable length, but our space will only allow us to refer to Sir William Congreve's plan, which has been in many cases adopted;—namely, to place large reservoirs of water on the top of a great building, from which pipes may descend to those parts most liable to fire, or which it is of the greatest importance to protect, so that the moment an accident occurs, the means are at hand for checking the flames. Thus, at the Royal Arsenal at Woolwich, there is a permanent reservoir of water 78 feet above the arsenal. The pressure of water from such a natural head produces jets of great power and effect in extinguishing flames.

It has been proposed to make the branch pipes, or a portion of them, proceeding from a reservoir of this kind, of fusible metal, so that, on the first breaking out of a fire, the pipes may melt and discharge water. This, however, would be of very little use, unless the fire happened to break out in so convenient a situation as to receive the jet of water directly upon it.

We may here also refer to Mr. Rutter's ingenious fire-alarum. An alarum apparatus is placed in the sleeping-room of the master, overseer, or watchman, and a galvanic battery in some other convenient apartment. A thermometer is also placed in every one of the apartments and passages of the house or building, and a double series of copper wires so laid throughout the premises, that on a given rise of any one of the thermometers, it shall immediately put the wires in communication with the battery and alarum apparatus, and so bring the latter into action. The thermometers are so constructed that metallic contact is formed, by means of platinum wires, with the separated parts of the copper wires leading from and to the battery, but in such a manner, that until the thermometers are acted on by a certain amount of heat, so as to cause the expansion of the air or other elastic substance within them, the current of electricity cannot pass from one part of the copper wire to the other; but as soon as this heat is applied, the mercury in the thermometers produces a continuous metallic circuit, and an electrical current will pass. In short, each thermometer, in its ordinary condition, interrupts the electrical current; and only in cases where great heat is produced near the instrument is the circuit closed, and the alarum apparatus set off. The alarum may be similar to that described under Electric Telegraph, Fig. 817.

We come now to the second part of our subject, which leads us to notice a few of the innumerable contrivances invented for the purpose of saving life and property from fire. The most obvious forms of Fire-Escape are ladders. These are provided by many parishes in London, and are hung up horizontally under a wooden cover by the side of the church. They are made of different lengths, to reach a first, second, third, or fourth story. The largest kinds are sometimes furnished with guides, or hand rails, and also with contrivances for raising them; one of which is a short conical iron tube, jointed to one of the upper rounds of the ladder; a long pole fixes into this tube, and affords great facility in raising the ladder. Another form of ladder, already noticed, and to be recommended for its portability and convenience, consists of short lengths, 8 or 9 feet each, fitting into each other to any required length, by a strong simple joint, in the same way as scaling-ladders. In Gregory's ladders the two parts or lengths are made to slide one upon the other, and can be sustained at any required elevation: a cradle is attached for the rescue of timid or infirm persons. Wire chain ladders, and rope ladders with wooden steps, have been arranged in a variety of forms as fire-escapes. One of the most ingenious is Adam Young's. This is a rope ladder with wooden rounds, at the top of which is a hooked frame for catching into the window-sill. In order to raise these hooks up to the window-sill, the rounds fit together so as to form a pole, each round being formed with a projecting pin at one end, and a socket at the other; so that, by fitting the pin of one round into the socket of the previous round, the hooks are gradually raised until they catch the window sill, a single jerk or pull at the lower end then disconnects the staves from one another, and they fall into their places as rounds of the ladder, while at the same moment the rope sides become distended. Gregory's rope-ladder escape is supported on the window-sill or parapet by a hook composed of two sides, or arms, bent so as to resemble the external figure of the human ear, and hence called an *ear-hook:* the two sides are held together by three horizontal iron rails, the rope ladder is attached to the hook, and a sliding cradle is also arranged, the rope by which the cradle is worked passing over the central bar of the hook.

Among the simplest forms of portable fire-escape is a good strong rope, with a hook or loop at the end, by which it may be fastened to a bed-post, so as to enable an active person to descend, a partial footing being found in the inequalities of the wall. The descent is greatly facilitated by having the rope knotted at intervals of about a foot, the knots enabling the hand to grasp the rope securely. A common bed-cord is usually strong enough to support the weight of a stout man; a quarter-inch rope will readily support 2 cwt. or three times that quantity if new and good. By attaching a sack to the end, and passing the rope once or twice round a bed-post, women and children may be lowered into the street. In the Great Exhibition were two or three forms of fire-escape adapted to the bed-room; in one form a wire-rope was coiled up upon a drum contained within an ordinary dressing-table, a handle attached to the axis of the drum allowing the rope to be gradually let down or wound up. In another form a strong staple is attached to the window-sill for holding a pulley, the rope of which has a small wooden seat or cradle attached to it, so that a person might let himself down with a second person in his lap merely by holding the rope, and allowing it to pass with regulated speed through his hands. By the same apparatus he could also ascend to the bed-room in order to rescue another individual. When not in use, the pulley with its rope and cradle may be kept under the bed, or in the dressing-table. Many of the portable fire-escapes conveyed to, not kept in the burning house, have been useless on account of the difficulty of establishing a communication with the persons in danger. This, however, may be effected by means of rods 6 or 8 feet long, connected either by fishing-rod, or bayonet joints, or by screws. In Edinburgh the firemen use a cross-bow, and a three-ounce leaden bullet attached to a cord 130 feet long. The bullet and cord are thrown over the house by the cross-bow: to this cord a stronger one is attached, and drawn over the house by the former, and so on, until a chain ladder or escape is elevated.

Of the larger kinds of portable fire-escapes, the most efficient is the *carriage ladder*. In 1809 Mr. John Davies submitted to the Society of Arts a fire-escape consisting of 3 ladders connected to, and sliding upon each other by means of ropes worked by a small windlass. A second windlass raised and lowered a cradle supported by ropes passing over pulleys at the top of the uppermost ladder. This machine was mounted upon a low four-wheeled truck, drawn by a horse, or by 6 men. This escape was improved by Mr. Gregory, who used 3 ladders sliding on each other, which, when lowered, were balanced horizontally upon a convenient frame, mounted on a light four-wheeled carriage, so as to be capable of being run under low gateways, &c. The ladders being brought into the vertical position, or nearly so, are raised by a small windlass in front of the machine to any required height between 10 and 40 feet; the ladders are then inclined towards the window, upon the sill of which the top may be made to rest. A greater elevation than 40 feet may be obtained by means of joints, to be carried up and fixed at the top. A cradle is also used with this machine for the benefit of those who cannot descend ladders.

Our limits will not allow us to devote more space to the description of fire-escapes. We are conscious of having omitted many meritorious forms; but the reader who is desirous of studying the subject is referred to Mr. Baddeley's excellent article in Hebert's "Engineer's and Mechanic's Encyclopædia," vol. i, 1838, to the volumes of the Mechanic's Magazine since that date, and also, to the Transactions of the Society of Arts. People are generally indifferent to this subject until danger actually threatens; but it would be at least prudent that the occupant of every bed-room should ascertain what are the facilities for ascending to the roof, and passing to that of his neighbour. In detached houses internal means of escaping through the windows ought to be provided, but, as Mr. Baddeley remarks, "people rather choose to trust to the chance of obtaining external aid." If this should not be afforded in time, "egress can sometimes be made at the top of a house, either by a door, or by an opening made in the roof with a poker for the purpose. Sheets and blankets tied together, and fastened to the bed-post, or the bed-cords attached in the same way, afford the means of descending; the feather-bed, &c. thrown out, serve to break the fall when jumping from the window, as the last alternative. With a little contrivance women and children may be lowered by means of the bed-clothes. Upon these occasions all depends upon the persons in danger retaining so much presence of mind, as will enable them to avail themselves of the best means in their power: and it often happens that pressing danger develops a great deal more ingenuity and intrepidity in individuals, than they have previously taken credit for."

The third part of our subject relates to the prevention of fires. The methods proposed for accomplishing this desirable end are, to make houses fire-proof either by coating the timber with some substance which would render it less inflammable, or to reject combustible substances altogether in house building.

In 1775 Mr. Hartley's method of rendering houses fire proof, was encouraged both by a patent and a parliamentary grant. Thin iron plates were nailed to the top of the joists, the edges of the sides and ends being lapped over, folded close, and hammered together. It was proposed to protect partitions, stairs, and floors in the same manner. The plates were so thin as to allow the floor to be nailed to the joists in the usual manner, and to prevent the plates from rusting, they were varnished with oil and turpentine. This method did not survive its inventor, nor was it likely to have been very successful, for when it is considered that iron is a combustible requiring only a higher temperature than wood for its destruction, we cannot suppose that any great amount of security is to be obtained from thin iron plates covering massive timber framing.

The Earl of Stanhope, among his numerous mechanical contrivances, had a method of fire-proofing which consisted in the use of a non-combustible material, with, among, and between the timbers used in the frame-work of a house. His methods are described under the heads *under-flooring*, *extra-lathing*, and *inter-securing*. Under-flooring is either *single* or *double*. In single under flooring a common strong lath of oak, or fir, about ¼ inch thick, is nailed against each side of every joist, and of every main timber supporting the floor which is to be secured. Other similar laths are then to be nailed along the whole length of the joists, with their ends butting against each other. The top of each of these laths, or fillets, ought to be 1½ inch below the top of the joists, or timbers, against which they are nailed, so as to form a small ledge on either side of the joists. These fillets are to be well bedded in a rough plaster, so as to leave no interval between them and the joists, and the plaster is to be spread on the tops of all the fillets, and along the sides of that part of the joists between the top of the fillets and the upper edge of the joists. In order to fill up the intervals between the joists that support the floor, short pieces of common laths, whose length is equal to the width of these intervals, should be laid in the contrary direction to the joists, and close together in a row so as to be in contact; their ends must rest upon the fillets, and they ought to be well bedded in the rough plaster, but not fastened with nails. They must then be covered with one thick coat of the rough plaster, which is to be spread over them to the levels of the tops of the joists, and in a day or two this plaster should be trowelled over close to the side of the joists, without covering the tops of the joists with it.

In double-flooring the fillets and short pieces of laths are applied as above directed; but the coat of rough plaster ought to be little more than half as thick, and while being laid on, some more of the short pieces of laths must be placed in the intervals between the joists upon the first coat, and be dipped

deep in it. They should be laid as close as possible to each other, and in the same direction with the first layer of short laths. Over this second layer of short laths must be spread another coat of rough plaster, which should be trowelled level with the tops of the joists without rising above them. The rough plaster may be made of coarse lime and hair, or chopped hay. One measure of common rough sand, 2 measures of slacked lime, and 3 of chopped hay, will make a good rough plaster. It should be made pretty stiff, and when the flooring boards are to be laid down soon, a fourth or fifth part of quick lime in powder should be added, which will cause it to dry quickly. When dry, should any cracks appear in the rough plaster near the joists, they are to be stopped with a mortar wash. Before the flooring boards are laid, a small quantity of dry sand should be strewed over the plaster work, and struck smooth with a hollow rule, moved in the direction of the joists, so that it may lie rounding between each pair of joists. The plaster work and sand should be quite dry before the boards are laid. The method of under-flooring may be applied to a wooden stair-case, but no sand is to be laid upon the rough plaster work. The method of extra-lathing may be applied to ceiling joists, to sloping roofs, and to wooden partitions.

The third method, inter-securing, is very similar to that of under-flooring; but no sand is to be laid on. This method applies to the same parts of a building as the method of extra lathing.

We notice these and some other methods without attaching much importance to them. Timbers coated with plaster, houses covered with fire-proof paint, soluble glass, and similar compositions, are not in many cases better calculated to resist fire than ordinary houses. If the house really contain a large quantity of goods and furniture, &c. of an inflammable kind, and the fire once obtain the mastery over them, we believe, notwithstanding the sham fire trials got up by the inventors of some of the fire-proof nostrums, that the house will share in the destruction of the goods. Indeed, we have had melancholy proof, that a house built of brick, iron, and stone, to the exclusion of timber, cannot by any means be said to be fire-proof, when the goods contained in it are inflammable. But we shall return to this subject presently.

A plan for the construction of floors and roofs has lately been advanced by Messrs. Fox and Barrett, who propose to substitute for the timber usually employed, joists of iron, and successive layers of incombustible materials, the floors being finished with a smooth and uniform surface, and the roofs with a coating of coal tar, paper and sand, the ordinary timber and slate roof being entirely superseded. The mode of finishing either the floors or the roof may, however, depend on circumstances, a surface of wood, straw, tile, cement, or other material, being readily adapted to the fire-proof foundation on which it is laid. The method of construction will be understood from Fig. 931, which represents in section one of the floors and ceilings. The joists J are of the T shape, reversed; they have a bearing of 6 inches on each wall, the ends being dove-tailed to form a sufficient tie. The strips which bear upon the flanges are generally formed of wood; but their ignition is said to be impossible, from the nature of the construction.

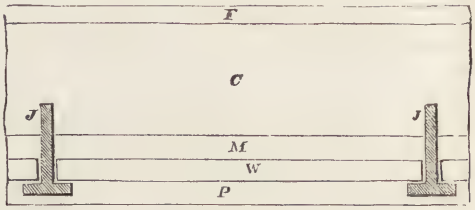


Fig. 931.

The coat of coarse mortar M is laid on about an inch thick, and forms a bed for the concrete C above, and together with the strips W, a key for the ceiling P below. The layer of concrete is about 5 inches thick, and may be formed of such materials as the locality of the building most readily supplies; road-grit, or clay from the foundation, mixed with a small portion of lime to bind it, answers well: gravel, burnt earth, clinkers, or broken brick, may also be used. The finished floor F is formed of a composition of lime and sand, well trowelled up to a face, and coated with linseed oil, which renders the surface hard, tough, and durable, and non-absorbent of moisture. The roofs are, for the most part, flat, and differ only from the floors in the method of finishing the surface. The ceilings are applied in the ordinary way, except that the usual ceiling laths are not required. The advantages of this plan are stated to be protection from fire, economy of construction, (the cost being said to be from 10 to 25 per cent. less than the ordinary method of flooring,) increased durability, security from the attacks of dry rot, and from insects and vermin.[1]

A plan proposed by Mr. Frost for the floors of rooms was, to use hollow earthenware tubes imbedded in cement, so combined as to cover the whole floor. The tubes are about 2 feet long, square in section, about $1\frac{1}{2}$ inch on the side, externally, with a tubular space of $1\frac{1}{4}$ inch on the side, internally. In forming a floor of these tubes, the centering, after being prepared and fixed in the usual manner, is first covered with a coating of cement sufficiently fine to form the ceiling of the apartment to be floored over, and if ornaments are required in this ceiling or its cornices, moulds for them are placed in the centering, so as to form a part of it. One or two coats of cement having then been laid over the centering, a stratum of square tubes laid side by side, and breaking joint, is imbedded in fine cement, and the interstices between them are filled in with that material. One thin coating of cement is then laid over the whole stratum; and in a week, when this is dry, another stratum of tubes is laid over the first in a contrary direction, bedded and filled in with cement as before, and finished with a coating of the same material. This, when dry, may have a second coating, to serve as the floor of an upper apartment, or the covering of the roof, as the case may be.

(1) From a pamphlet published in 1849 by the inventors.

The following general directions, for the construction of fire-proof houses of small size, are given by Mr. Loudon, in his "Cyclopædia of Cottage, Farm, and Villa Architecture" (London. 1833—1842). The floors may be formed of flat tiles and cement, and covered with ornamental tiles; or flooring may be made of composition, and polished in imitation of scagliola or artificial marble. The roofs may be made flat, and covered with common cement, and the outer walls of the building may be tied together in all directions by wrought-iron rods made fast to stone bond, as broad as the wall is thick, the stones cramped or dovetailed together, and carried completely round the walls, about the level of the centre of each floor. The netting or lattice-work of iron rods connected with this chain of stone bond being thickly imbedded in cement, and cased with strata of flat tiles, would be kept from extremes of temperature throughout the year; so that the difference in their contraction and expansion during summer and winter would be of no practical importance. Every floor of a house thus formed would be in effect a single flagstone, and, as the iron rods would be prevented from oxidising, it would probably last for ages. It is easy to conceive the skeleton of an entire house thus constructed; the perpendicular supports being brick or stone piers, 3, 4, or 6 feet apart; the horizontal bonds on these supports of flagstone, of the width of the intended thickness of the walls or partitions, and all the horizontal floors or vertical panels of iron rods and wires covered on one or both sides with plain tiles coated with cement. Even the staircases might be so constructed and covered. In the case of the floors of rooms, square or nearly so, there might be circles of thin flat cast-iron laid on the horizontal rods, and made fast to them, which would serve as struts; and oblong rooms might have two or more cast-iron circles, or ovals, with plates of cast-iron in the direction of their short diameters, to serve the same purpose. The outer walls might have double panels of wrought-iron rods and wires, with intervals between, so as to form hollow walls; so that houses constructed in this manner might be rendered equally impermeable by cold or heat as those with thick walls, or with hollow walls of masonry. There would be no objection to houses of this description having all the doors and windows framed of timber, provided the panels and astragals were filled in with iron. As the iron rods and wires need not be of great diameter, (perhaps, in ordinary cases, of half an inch for the rods, and one-eighth of an inch for the wires, and half an inch in thickness with 3 inches in breadth for the cast-iron circles,) the expense even for the smallest house would not be an insuperable objection. Were the attention of the legislature turned to this subject, with the view of protecting those who at present cannot protect themselves,—we mean dwellers in town houses of the commoner kinds,—the Government would probably direct experiments to be made so as to bring this mode of construction, or some similar mode, to a degree of perfection which would soon render it general.

Attempts have been made to render houses fire-proof without abolishing the use of timber in their construction. It has been proposed to make the timber itself indestructible by fire, for which purpose Mr. Payne, whose wood-preserving process is well known, has patented a method for rendering timber fire-proof by means of a solution of sulphuret of barium or calcium. The wood or other vegetable matter is put into an air-tight vessel, from which the air is driven out by means of steam: the steam is condensed by the injection of the solution of the sulphuret, and by the application of cold water to the outside of the vessel. A partial vacuum being thus obtained, the solution is allowed to flow into the vessel from the reservoir containing it through a pipe furnished with a stop-cock. The stop-cock is then closed, and an air-pump connected with the vessel is worked until as perfect a vacuum as possible is obtained within the vessel. The cock is again opened so as to allow the solution to fill the vessel nearly. It is then shut, and by means of a force-pump a further quantity of solution is introduced, until the pressure on the interior of the vessel amounts to from 110 to 140 lbs. on the square inch. This pressure is maintained for an hour, and the solution is then drawn off. The vegetable matter is next impregnated in a similar manner with an acid, or a solution of some substance, such as sulphate of iron, which will unite with the barium or calcium and set the sulphur free. When the vegetable matter is to be impregnated with a large quantity of solid matter, it should be dried between the application of the two solutions.

Without entering into any further details at present respecting the construction of fire-proof buildings, or stopping to point out the various methods in which iron joists and girders have been and are being extensively employed in large structures, we conclude by calling attention to a statement made about three years ago, by Mr. Braidwood, on the subject of fire-proof buildings, to the Institution of Civil Engineers. He exhibited a collection of specimens of cast-iron which had been used in the construction of buildings destroyed by fire, which showed that occasionally the temperature in the conflagration of large buildings rose almost to the melting-point of cast-iron. It was also stated that, even in a small fire, beams and columns of cast-iron would be so affected by the heat and jets of water upon them, that they would probably be destroyed, and sometimes cause great loss of life; as, in many of the so-called fire-proof warehouses of London, a number of persons employed on the premises slept in the upper floors, and if the lower beams gave way, the whole would be dragged down suddenly; whereas, timber beams resisted fire some time, and allowed time for the inmates to escape. The firemen, also, were liable to more danger from the same circumstance, as the only chance of extinguishing fires was to send them into the buildings with the branches and water-hose; but where the danger was so evident, the men were forbidden to enter, and their efforts were limited to preventing the fire from spreading. The expansion of the iron beams at high temperatures, and their sudden contraction on the application of cold water,

caused a derangement of the brick-work: the mortar, also, frequently became completely pulverised by the excessive heat.

In the construction of fire-proof buildings, Mr. Fairbairn proposed, 1. That the whole of the buildings should be composed of incombustible materials, such as iron, stone, or brick. 2. That every opening or crevice communicating with the external atmosphere be kept closed. 3. That an isolated stone or iron staircase be attached to every story, and be furnished with a line of water-pipes, communicating with the mains in the street. 4. That the different warehouses be divided by strong partition-walls, and that no more openings be made in them than are absolutely necessary. 5. That the iron columns, beams, and brick arches be of sufficient strength not only to support a continuous dead pressure, but also to resist the force of impact to which they are subject. 6. That, in order to prevent the columns from being melted, a current of cold air be introduced into the hollow of the columns from an arched tunnel under the floors.

Mr. Braidwood argued, that if the second principle could be enforced, a fire would go out of itself; but it was doubtful whether the object was not defeated by carelessness in leaving a door or window open just at the time when a fire occurred. The fifth condition does not allow for loss of strength in iron consequent on high temperature; and the sixth was held to be insufficient, as a specimen of $1\frac{1}{2}$ inch cast-iron pipe, on being heated in the centre, with both ends open, and a current of air passing through it, gave way, after an exposure of only four minutes in the fire, on one end being held in a vice, and the other pulled with slight force by the hand. It was recommended that iron should not be used, but groined brick arches, supported by pillars of the same material laid in cement. Warehouses should also be built of a more moderate size, and be completely separated from each other by strong party walls.

FIRES, Lighting of. There is much philosophy in common things, as may be illustrated by the apparently simple operation of lighting a fire. In this process we take advantage of the easy combustibility of one material to produce combustion in a second material, which is not so readily ignited: and this in its turn acts upon a third material, which is still less easily ignited. The paper burns easily and quickly, and kindles the wood, which burns less easily, and this in its turn raises the coal to a sufficiently high temperature to burn. The laws which regulate the draught of a fire were considered in the article Chimney; but we may here notice a method of lighting a fire recommended many years ago by Mr. Gill, in his "Technical Repository," and which certainly does appear to deserve the praise which he bestows upon it:—Fill the grate with fresh coals quite up to the upper bar but one; then lay on the wood in the usual manner, rather collected in a mass than scattered; over the wood place the cinders of the preceding day, piled as high as the grate will admit, and placed in rather large fragments, in order that the draught may be free: a bit or two of fresh coal may be added to the cinders when once they are lighted, but no small coal must be thrown on at first. When all is prepared, light the wood, when the cinders in a short time becoming thoroughly ignited, the gas rising from the coals below, which will now be affected by the heat, will take fire as it passes through them, leaving a very small portion of smoke to go up the chimney. One advantage of this mode of lighting is, that small coal is better suited to the purpose than large, except a few pieces in front, to keep the small from falling out of the grate. It is stated that a fire lighted in this way will burn all day without anything being done to it. When apparently quite out, it will glow up on being stirred. When the upper part begins to cake, it must be stirred, but the lower must not be touched. Mr. Gill says that, on trying this plan with a common Bath stove, about 14 inches wide at the top, a fire lighted at 8 A.M. continued burning until 5 P.M. without being touched. The apertures at the bottom of the grate must be kept closed, either by the dust and ashes of the former day's fire, or by means of the small coal-dust contained in the coal used for lighting the fire. In this case it will continue to burn with a smouldering heat for thirteen or fourteen hours, with so little consumption of fuel, that at the end of that time, on being stirred up, and air admitted, a lively fire is produced. Even when smouldering, the fire gives out a moderate degree of heat.

FISH-HOOKS. The manufacture of these little articles requires a considerable amount of skill, attention to the material, and the method of manipulation, which, being practised by the manufacturers of one district, and not by those of another, have made the one celebrated, the others inferior. Thus, the Limerick fish-hooks have long been esteemed by anglers for salmon and trout-fishing: they are made of cast-steel, forged square by nailers, with solid wedge-shaped pieces at the end of each, out of which the barbs are formed by filing. The shanks are then filed round, and, after being bent to the required curve, they are carefully hardened, and tempered by being placed upon a plate of iron and heated until a drop or two of tallow let fall upon the plate smokes or blazes: this points out the proper tempering heat, according to the quality of the steel employed.

The barbs of the English hooks are cut with a knife, instead of being filed out of the solid. Fig. 932 is an enlarged representation of one of the real Limerick hooks, the barb of which had been filed out of the solid from a piece of steel shaped like Fig. 933.

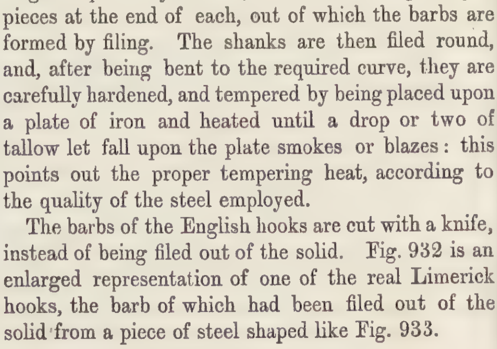


Fig. 932.

Fig. 933.

Sir Humphry Davy in his Salmonia describes the method of making the Limerick hooks. The first requisite is the softest and purest kind of malleable iron, such as is procured from the nails of old horse-

shoes. This is converted into steel, and the steel into bars or wires of different thicknesses for different sized hooks, and then annealed. For the larger hooks, the bars must be made in such a form as to admit of cutting the barbs; and each piece which serves for two hooks, is larger at the ends, so that the bar appears in the form of a double-pointed spear, 3, 4, or 5 inches long: the bars for the finer hooks are somewhat flattened. The artist works with two files, one finer than the other, for giving the point and polishing the hook; and he begins by making the barb, taking care not to cut too deep, and filing on a piece of hard wood such as box-wood, with a dent to receive the bar, made by the edge of the file. The barb being made, the shank is thinned and flattened, and the polishing file applied to it; and by a turn of the wrist round a circular pincers, the necessary degree of curvature is given to it. The hook is then cut from the bar, heated red-hot by being kept fòr a moment in a charcoal fire; then plunged, while hot, into cold water; then tempered by being put on heated iron till it becomes a bright blue; and whilst still hot, it is immersed in candle-grease, where it gains a black colour: it is then finished.

Mr. Gill says[1] that, on examining some of the London Limerick hooks, as they are called, with a microscope, he found that, although the barbs had a shape somewhat resembling the real Limerick ones, yet they had first been cut with a knife, in the usual manner of making English hooks.

The village of Redditch, in Worcestershire, the chief seat of the needle trade, produces most of the English fish-hooks. The manufacture both of fish-hooks and needles was illustrated in an agreeable manner at the Great Exhibition by men who went through all or most of the operations required in the production of those articles. The first operation in making fish-hooks is to cut the wire into lengths, which vary according to the quality of the hook: thus in Fig. 934 *e* is the finished work made out of the

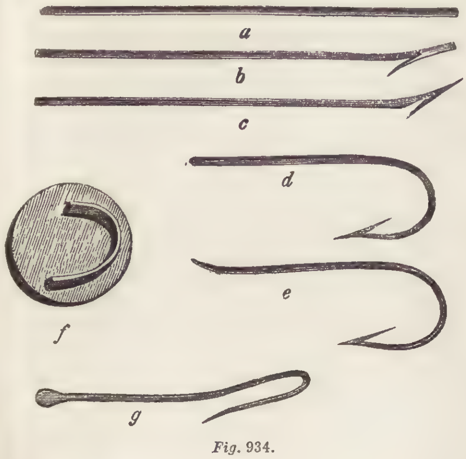


Fig. 934.

wire *a*. The lengths of wire are softened by heat in a furnace. A small standard, about 2 inches in height, 1 inch long, and half an inch broad, is fastened to the bench at which a workman is seated. On the upper face of the standard are three holes, into which the ends of three wires are inserted. The holes are so contrived that the wires are all at the same distance from each other, and their ends in the same line; so that if a mark is made across three wires inserted in the holes, the mark is upon each at the same distance from the ends. In this way, thousands of wires, originally of the same length, can be marked, all the marks being equidistant from the ends. By the side of this standard is a contrivance for supporting a knife which can be moved with a certain force in one particular direction. The workman, thus provided, takes up three wires of the proper length, and inserts their extremities into the three holes: he rests the point of a narrow-bladed knife in the rest, and pushing the knife from him towards the point of the wires and along their upper surface, beginning at a certain point near the end, he cuts up a portion of the metal, as in *b*. Entering from the surface and going gradually deeper, the barb or *beard* is thus pointed. Taking out the three wires, he throws them aside, and cuts another three as before. Some skill is required in inserting the three wires into their respective holes, in adjusting the knife so as to commence the cut exactly in the right place, and in making the cut of the proper depth, so as to give the required length to the barb. The next operation is to point the end of the hook, as at *c*, which is done by filing, the wire being grasped with a pair of plyers, and the end placed on a piece of box-wood. The hooks are next to be rounded, or bent into the circular form. This is done by means of a small block of wood, from the end of which projects a piece of thin brass bent as at *f*. At one end is a small notch, into which the barb is placed: the wire is then twisted over the convex surface of the brass, which gives it the bend shown in *d* and *e*. The wire is not bent round equally, but rises somewhat; that is, the man does not bend the wire round the brass slip on the same level, but in approaching the end, he raises his hand, and thus the hook is bent upwards at a particular part. A man can bend almost sixty hooks in a minute, giving to each one the particular bend required. The end of each hook is next flattened, as at *e* and *g*, to afford a hold to the silk or other fastening used for uniting the hook to the fishing-tackle: this is done by giving the end, which is placed on an anvil, a smart blow with a small hammer. The hooks are next hardened; then tempered at a sand-bath heat, properly regulated; next scoured in a rotating barrel, containing emery and soap; and lastly, blued at the required heat in a sand-bath.

FIXED AIR. See Carbonic Acid—Coal.

FLAME. See Candle.

FLANNEL. See Wool.

FLAX, (*Linum usitatissimum,*) an annual plant of fragile appearance, sending up slender fibrous stalks, two or three feet high, with narrow alternate leaves, and delicate blue flowers. These are followed by globular, many-celled seed-vessels, containing bright

(1) Technical Repository, vol. iv

slippery brown seed, flattened and elongated. The stalks of this plant are hollow pipes, surrounded by a fibrous rind, the filaments of which furnish to the manufacturer the material for cambric, linen, and other similar fabrics.

Fig. 935. FLAX.

The frequent mention of fine linen in Scripture must be remarked by every reader of the Old Testament, and the evidence which is afforded by the unrolling of Egyptian mummies, that the fine linen of Egypt was actually woven from flax, is sufficient to prove that the same plant which we now employ, furnished one of the most ancient manufactures known. The fineness of some of this linen compared with what is woven in Egypt at the present day, also shows that the ancients had arrived at a high degree of skill in the preparation of this valuable substance.

From the time of the Romans, the produce of flax has been known in the British Isles, but our country has been very slow to avail itself of the fact that the plant can be successfully cultivated on British soil. Notwithstanding various inducements that have been held out by the government, flax has been neglected, or only very partially grown; it has also obtained a bad report, as an exhauster of the soil, while in fact, the imperfect mode of culture, and not the plant, is in fault.

Recent discoveries have, however, given a new importance to the cultivation of this crop, and flax now promises to afford a British material for British manufacture, instead of being ranked among foreign and imported goods.

"The animal and vegetable world," says Mr. Mac Adam,[1] "pretty equally divide the supply of the principal articles of clothing required by the human race. From the former we obtain wool and silk; to the latter, we are indebted for cotton and flax. Of these four substances, which enter into the composition of at least nine-tenths of the clothing of the civilized world, one (cotton), is the exclusive production of the regions bordering on the torrid zone; another (silk), although it has, to a trifling extent, been cultivated in Great Britain, may also be considered as naturally the production of the same countries, since the silk-worm does not flourish so certainly in our climate; a third, (wool) is largely obtained at home, and gives employment to a flourishing branch of British farming; yet it is understood that the wool of our islands is inferior for felting to that of foreign countries, and cannot be substituted beyond a certain proportion, or for certain kinds of cloth. The last mentioned, flax, is the only one of the four for which our soil and climate are absolutely suited, and where a native-grown article might be substituted to a very large extent, if not altogether, for the foreign import."

It is calculated that upwards of one-tenth of our whole population is dependent upon the various branches of the cotton, flax, wool, and silk manufactures, and that the capital embarked in them is not less than one hundred million pounds sterling. The whole of the raw material employed in these manufactures is in one form or other obtained by agricultural labour; yet of this labour only an extremely small amount is furnished by the inhabitants of Great Britain. Perhaps it is this fact more than any other, that has given rise to a spirit of rivalry between manufacturers and agriculturists, and to a jealous apprehension that the prosperity of the one is attained at the expense of the other. In support of this surmise, we may notice that the woollen manufacture, which really does bring into request a regular amount of home labour, is viewed with far more friendly feelings by cultivators of the land than any other branch of factory employment. Their interests are immediately concerned in its prosperity, for although British wool is seldom used without some admixture of foreign, yet the wool market is a most important source of profit to the farmer, and there is a constant demand for the produce of his flocks, with a fair encouragement to attend to the improvement of the fleece. The cotton and silk trades must in the nature of things be carried on independently of the British farmer, but we trust there will not long exist a reason why we should be altogether dependent on foreign nations for our flax, and why the small degree of cultivation long bestowed upon this crop in the sister island, should not extend till it becomes a large and important branch of farming operations throughout the country.

The Royal Agricultural Society of England deemed the subject of the growth of flax in these islands of sufficient importance to warrant their offering a prize for the best essay on the reasons, general and particular, in favour of extending the growth of flax in this country, and what are the considerations adverse to this practice, the most approved methods of cultivating the plant, the best mode of saving the crop, and preparing the flax for the market, and in what way the whole or any portion of the seed may be saved with the least injury to the fibre, and how the seed may be most profitably applied by the farmer. The successful essay was that of Mr. Mac Adam, from

(1) "On the Cultivation of Flax," by James Mac Adam, Jun. Secretary to the Society for the Promotion and Improvement of the growth of Flax in Ireland. This Essay obtained the Prize of Twenty Sovereigns, or a piece of Plate of that value, offered by the Royal Agricultural Society of England, and is inserted in the Eighth Volume of the Society's Journal.

which we derive some important particulars affecting the question.

Flax is indigenous to several countries of the East, where it has been grown, spun, and woven into textile fabrics from a remote period of antiquity; but it is found to be specially adapted to temperate climates, so that when transported from the warm climates of which it is undoubtedly a native, the quality of the plant for the finer purposes of manufacture is considerably improved thereby. Flax is grown at the present day in all the northern countries of Europe, as well as in Sicily, Italy, and on the coasts of the Mediterranean, to a considerable extent in India, and latterly it has much increased in Egypt; North America also produces much flax, principally valued for its seed. To Britain it was brought by the Romans; but it was probably known in Ireland at a much earlier period, by means of the Phœnicians.

A slow steady growth is required to produce the best quality of fibre in this plant; when reared in hot countries, the seed is superior in quality, but the fibre is wanting in delicacy and elasticity. Egypt is in some degree an exception, for the flax grown there is favoured by the rich alluvial soil of the Nile; yet with this advantage, and with every effort to improve the cultivation, it still fetches an inferior price in the market. On the other hand, in countries approaching the northern limits of the temperate zone, the short hot summers induce too rapid a growth, and although the quantity of fibre is good, the quality is not first-rate. This is the case with Russia, which out of an export reaching to 40,000 or 50,000 tons per annum, does not sell at a higher price than 48*l.* per ton, while the flax of Holland and Belgium sells at 150*l.*, or sometimes 180*l.* per ton. The consumption of flax varies in this country from 80,000 to 105,000 tons per annum, and of this about 35,000 tons are estimated as the produce of the British Isles, chiefly of Ireland.[1] The greater part of this amount is spun and woven into various fabrics, from the coarsest canvass to the finest cambric, but a great deal is exported as yarn to Germany, France, and Spain, where it may take the form of the roughest sail-cloth, or be manufactured into the most delicate lace. Our imports of flax, in the form of fibre, seed, and oil-cake, are extremely large. In 1844, they amounted to a sum exceeding six millions sterling, and since that year the quantity has been on the increase.

The capability of Great Britain and Ireland to produce this crop in perfection is now generally admitted; but the want of care in its cultivation, which characterises our people, and especially the Irish peasantry, is also fully known. Among the documents published by the Belgian government in 1841, on the cultivation of flax in that country, is one in which the following statement occurs:—

" The flax of Ireland, when first pulled, is as good as ours, but the Irish are negligent. Our flax is immediately put in water, theirs is left to get heated in the air, while they go away to drink and enjoy themselves. Our peasants are watchful, and take out the flax at the end of five or of eight days, according to the condition they find it in, the Irish do it just when they please. Our flax, when covered with mud, is spread out carefully in a fine meadow, when the first shower cleanses it; in Ireland, it is thrown down almost anywhere. The women, with us, often take the preparation of the flax upon themselves; but in Ireland, the flax is prepared in mills. We have sent some families to England, who have since returned, and they inform us that very good flax could be reared in that country. During the war, when neither we nor Holland exported flax, the English contrived to produce equally good linen with that which they manufacture at the present time; they then cultivated good flax in Yorkshire and in Ireland, but since that time they have neglected its culture."

In confirmation of this favourable opinion of British flax, we have the fact that some fine samples, grown in Norfolk and Bedford have realized, the former 85*l.*, the latter 100*l.* per ton, while occasional samples of Irish growth have brought as high prices as the best Belgian flax. The entire quantity required for British manufactures might undoubtedly be grown at home, with great advantage to our islands, were the culture sufficiently understood to make these favourable results more frequent, and could a ready market be obtained. In that case, the crop would occupy nearly 400,000 acres annually, and if the amount required for feeding cattle were added to this, not less than half a million acres would be needed for the flax crop of Britain.

Our climate is peculiarly adapted to the growth of flax, but some districts are more favourable than others. Those which possess the most equal temperature are the best. A regular supply of genial moisture in spring, without an excess of wet in autumn is most advantageous, and the plant will flourish at a considerable altitude under such circumstances, having been grown with success in county Wicklow, Ireland, at a height of 1060 feet above the sea level.

Our spring is more favourable to flax than that of Belgium, since the long and severe droughts in that country cause the crop to fail every three or four years, from this cause alone. But our summer is not so favourable as theirs, for towards the end of July when the pulling time approaches, the heavy rain and perhaps hail which we frequently have, is very injurious to the crop, causing it to rot upon the ground, or discolouring the stalk in a way which no after care can remove. In growing flax, an open situation is to be chosen, and by no means a field sheltered with trees.

This crop accommodates itself to a great variety of soils; flourishing on sandy loams, light and heavy clays, marly, peaty, chalky, or alluvial soils. But a mixture of sand and clay is considered the best, especially where the subsoil is of clay. Very light sandy soils will not afford good crops without a large supply of manure. Flax worth 70*l.* per ton has been

(1) Ireland produces from 25,000 to 30,000 tons per annum: the remainder is grown in Yorkshire, Somersetshire, and the south of Scotland.

grown on an Irish bog, reclaimed three years before, and having a subsoil of gravel and clay. Flax will not bear to be sown at very small intervals on the same soil. In this respect the practice of the Irish and Flemish is to be condemned. It was formerly sown, as a general rule, after potatoes; but this custom has given way to the better plan of sowing on wheat, oats, or barley stubble, which ensures a much better quality of fibre, though not quite so full a crop. Very good crops are also obtained after clover lea.

One of the greatest advantages attending the culture of flax is, the short time it occupies the ground; namely, from April to July. This allows of another crop being taken from the soil during the same season. Grass or clover is generally sown with flax in this country, so as to give a crop the following year; but in Belgium the white carrot is frequently sown broad-cast with flax, and the pulling of the flax loosens the mould round the young plants, so that they increase rapidly afterwards, being generally top-dressed with liquid manure. Rape, winter-vetches, or turnips of the stone or Norfolk globe varieties, may be advantageously grown with flax, and used before the following spring. Flax culture can generally be best followed after any white crop, except on very poor land: soil which has lain long in pasture has yielded valuable crops of flax, having been planted first with potatoes, then with grain, and afterwards with flax.

After thorough ploughing and pulverization of the soil, the land for a flax crop is laid out in broad flats, not in ridges, and a roller is passed over the ground to consolidate the surface. A short-toothed harrow follows, to prepare for the seed, which is carefully chosen, Riga seed being the favourite in England and Ireland. This is received in barrels, containing 3½ bushels, and covered with a coarse linen bag. The barrels are branded in Russia by government officers named *brackers*, who classify the seed as it arrives from the interior, and arrange it under the terms, "sowing seed," "rejected sowing seed," and "crushing seed." These varieties are sometimes, however, fraudulently mixed. Dutch seed, reared from Riga, but of the second year, is also much esteemed: in some respects it is superior to Riga, being generally unadulterated, and much more carefully cleaned. The respectability of the dealer is the best security for obtaining good seed. That which has a shining slippery appearance, and a brownish red colour, without being too plump, is the best. The quantity sown per acre varies from two to three bushels; the former for poor, the latter for rich soils. Thin sowing promotes a coarse growth of the plants, and deteriorates the fibre: thick sowing induces the plants to spring up with tall and slender stems, of fine fibre. The seed is sown broad-cast, and another person follows immediately after, to scatter clover or grass seed. The whole is then covered by a light seed-harrow, and rolling finishes the process. It is established as a good system, and a great saving of expense, for the English grower to save sowing seed the first year from Riga or Dutch seed. Some now sow all from their own seed, except an acre or two from foreign seed, to keep up the supply.

When the young plants have risen to the height of two or three inches, they are carefully weeded by women or children, creeping along upon their hands and knees, and keeping their faces to the wind. This does not crush the plants so much as trampling on them by the feet; and if it be done on a breezy day, the wind will soon raise the young plants to their former position. In Belgium and Holland the crop is weeded twice or thrice in this way. In this early stage the flax is in its most critical position: very dry weather will scorch its delicate fibres, and cause it to wither and die. A water-cart has in some cases been used with good effect, going regularly over an acre a-day. The delicate blue blossoms of the flax open in June, when it is one of the most beautiful of crops. These are succeeded by seed-bolls, the state of which affords the best criterion for judging of the maturity of the crop; therefore they are to be frequently examined. The Dutch method is daily to take one of the ripest capsules and cut it horizontally with a sharp knife: if the interior is whitish and watery, the crop is not ripe; if it be firm and of a dark green, the flax is fit for pulling. If left long after this, the seed will drop, and the plant will die; but it must be pulled before its juices are exhausted, and while the fibre is consequently silky and elastic.

The great objection urged against the culture of flax is, that it is an exhausting crop; and this is quite true, for it abstracts a larger amount of nitrogen from the soil than many other crops. But under the new mode of management, copied from the careful systems of the Continent, this objection is completely set aside. The restoration of the steep-water and of the woody portions of the plant, with the husks of the seed, to the soil, completely renovates the land, making it as well fitted to produce any crop as before. Formerly, the most wasteful system was employed in this respect. The flax was pulled without the separation of the seed, which was consequently lost; and the steep-water and other refuse was never economised for manure. The large amount of labour required to grow and prepare it is another objection; but where labour is plentiful this can scarcely be maintained as an objection, especially as the value of the fibre increases according to the trouble and care with which the various processes are carried on. The flax districts of Belgium are able to boast of having no poor, for the whole population is employed in the work during the winter.

The motives to a fair trial of this crop at the present period are very many. Not the least important is that which arises from a deficiency in the supply of cotton from the United States, which deficiency threatens ere long to throw a large number of our working population out of employment. Recently, also, there are signs of a similar deficiency with respect to flax, and the linen trade is confessedly retarded by the limited supply of the raw material from Russia, Belgium, and other flax-producing states. It is, therefore, not without reason that enlightened agriculturists, both of England and Ireland, have taken up

the subject, and that the Royal Flax Society is labouring to disseminate sound information respecting the culture of a plant which has been viewed with prejudice on account of former imperfectly conducted attempts, which led to no favourable results. One thing is certain: flax is well adapted to our soil and climate. It has been grown upon reclaimed Irish bog, on the summit of the Wicklow mountains, and on the western shores of Galway and Mayo; in the highlands of Scotland; in the fen districts of England; upon the Beacon Hill in Norfolk, and in the midland counties: upon every variety of soil.

Under the present mode of treatment it is by no means an exhausting crop. Lord Monteagle states, that the cultivation of flax has actually improved some poor land on his estate; and that no meadow yielded such capital grass as that on which the flax had been grown. Other experienced flax-growers have obtained similar results. And not only is this crop non-exhaustive, under proper management, but it is also fairly remunerative to the grower. In a report of the Royal Irish Flax Society, particulars are given of the flax-crops of fifty-one farmers of the county of Down, the average profit being at the rate of 7*l.* 1*s.* 4½*d.* per acre. This was from the fibre only, for not one of these growers saved the seed. Where the plant is cultivated with a view to the seed alone, and the stalk is merely used as litter, the results are also very favourable. The published experience of a grower who saved both seed and fibre shows that a profit of 6*l.* per acre over that of the wheat crop may be obtained in this way.

The reason why the culture of flax, under these encouraging circumstances, does not become rapidly and generally prevalent, has yet to be told. There is at present a certain degree of difficulty and uncertainty in finding a market for it. Lord Monteagle has laboured to restore the cultivation of flax in his part of Ireland, which, he says, had ceased "on account of the want of markets for the produce." His tenants, with those of the Earl of Devon and other influential landholders of the district, had responded to his labours, had grown good flax, and received the favourable notice of the Flax Society. His lordship's own sample was valued at 63*l.*, when prices were very low, and would have afterwards been 100*l.* His tenants did not, however, succeed so well as himself: they could not transport the flax in its bulk; they had no water-power, and he was unwilling to erect steam power till assured of a market. The consequence was, that he had to take all the flax off the hands of his tenants, and so became the possessor of more stacks of flax than of wheat, and without the means of turning them to account. While things are in this state, it is impossible that flax-culture should flourish. Few persons will persevere in taking all the trouble and risk which certainly belong to this crop, unless they are certain of a ready and profitable market. M. Claussen's recent invention, as will be shown in the next article, will probably have the effect of opening new markets for home-grown flax.

The extensive use of oil-cake for the feeding of cattle points out a great advantage to the English farmer in the cultivation of flax, over and above the actual value of the crop in other respects. The production of flax-seed on the farm would obviate the necessity of purchasing costly feeding materials, while it would also supply oil, in the course of the manufacture of oil-cake. To make this cake, the seed is crushed between metal rollers, then ground under edge millstones, then heated in a metal vessel, where it is constantly kept stirred by machinery, and the oil is extracted by pressure. What remains is the oil-cake. Horses, cows, and pigs are greatly benefited by this food. The ground-seed is also made into gruel by steeping for a day in cold water, and mixing with milk and lukewarm water at feeding-time. This is much used for young calves in the north of Ireland. In all cases where linseed is given, it should be thoroughly crushed, and ground into meal. Efficient machines for this purpose are made by the agricultural implement makers. One of these for engine or horse power is shown at Fig. 936.

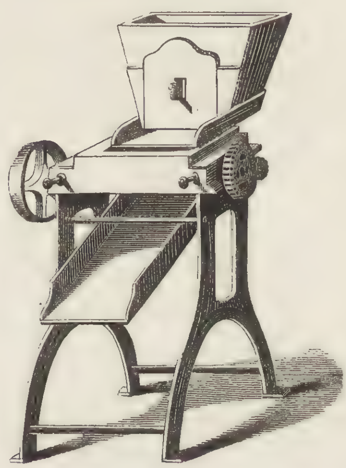


Fig. 93o.

Rippling. After pulling, the general practice is to *ripple* the flax immediately. By this term is meant the separation of the seed from the stalk, which is done by drawing the latter briskly through a machine shown in Fig. 937, composed of a row of iron teeth, about 18 inches long, half an inch square, a quarter of an inch asunder at the bottom, and tapering slightly, so as to be half an inch asunder at the tops, which are sharpened. These teeth are screwed into a flat piece of wood or of metal, which can be bolted down to a bench or plank on which the operators sit astride, facing each other. Handfuls of flax are laid at the right hand of each rippler, and spreading it out like a fan, each draws his handful alternately through the ripple, allowing the seed-bolls to fall into a winnowing-sheet placed below to receive them. Four men, with two rippling-combs, will take the seed off more than an acre of

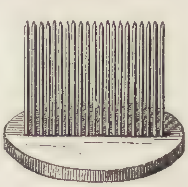


Fig. 937.

flax per day. The ripplers lay down their handfuls on the left-hand side, where they are tied up in sheaves, and carried at once to the steep-pool. The seed-bolls, meanwhile, are dried, and stored away in bags in an airy place. They should be *well dried*, or they will heat. Mr. Richard Robinson, of Belfast, has invented an improved machine for seeding flax, and also a machine for cleaning the seed.

STEEPING OR RETTING. Flax is the filamentous portion of the stalk of the plant, from which it is necessary to separate the woody part termed the *boon.* But in order to do this, the gum or resinous sap which binds the parts together must be dissolved; and the method of doing this greatly influences the value of the fibre.

The steeping of flax is carried on in some places by mere exposure on the grass to dews and rain, which is called *dew-retting*, *rating*, or *rotting;* in other places, by immersion in running streams. But the plan commonly adopted is that of steeping it in pools or pits filled with water; this is called *water-retting.* The quality of the water must be taken into consideration. It must be free from iron or other metallic particles, or the fibre will be discoloured: it must not be hard or spring water; but, if possible, it must be water that has flowed for some distance exposed to the action of the air. Flax is improved by a very gentle current flowing over it; and although our rivers are too rapid to allow of our steeping it in them, yet the steep-pool is most perfect when it is in communication with a river, and can have a slight current on the surface, sufficient to carry off the scum. If river-water be not available, spring-water should be let into the pit six weeks before the flax is put in, that it may have time to mellow and to deposit any calcareous sediment. In the steep-pool the sheaves of flax are packed loosely, resting on their butt-ends. It is best to put but one layer of sheaves into the pool. The flax must be covered from the light by sods, with the grassy side underneath, or by wheaten straw, kept down by stones or logs of wood. After a time, fermentation, accompanied with an unpleasant odour, ensues; but this is said to be innocuous. The water poisons fish; but cattle are not injured by it, as is proved on the banks of the Lys, where cattle drink freely of the water, while the river is full of flax for miles. The steeping of the flax must be continued until the gum-resin which binds the fibres together is completely loosened and separated; but it must be stopped before the putrefactive fermentation takes place. In order to this, a careful examination is necessary. One of the signs of the approach of this result is the sinking of the flax in the water, which may take place, according to the weather, after from six to twenty days' steeping. But a better test is the breaking of a few stalks of average fineness, and ascertaining whether the fibre can be easily pulled off, without breaking, from the internal woody part or *boon.* If so, the flax is sufficiently watered, and a longer stay would make it weak and cottony.

The removal from the steeping-pool requires care. The covering of straw is first removed to the manure-heap, being a valuable addition there, on account of its being saturated with the water of the pool. A person then stands in the water, lifting out the bundles of flax without the use of pitchfork or hook. Others receive the bundles, and set them up on their butt-ends to drain for twenty-four hours, after which they are spread out on the closest and shortest pasture, and left to be washed by showers, and softened by the action of the air. They should be evenly spread in rows, so that by means of a lath they may be turned over easily, that each side may be exposed alike, otherwise, a difference in quality and colour is the consequence. A few days or a week is occupied in grassing, after which the flax is lifted, tied up in sheaves, and packed under cover, or stacked and thatched in the rick-yard. Here it may be kept for years; the quality rather improving than deteriorating during three or four seasons after steeping.

By the old methods of *water-retting* and *dew-retting* the plant is brought to a certain stage of decay, which causes a loosening or separation of the fibres. By either procsss, from 10 days to 3 or 6 weeks is required before the flax is ready for separation from the boon, and in the meantime the waters and the atmosphere of the district are rendered offensive, and the flax itself may be stained or injured by over retting. In 1847 an improved plan of retting was introduced into Ireland by Mr. Schenck of New York, and is thus described by a writer in Newton's London Journal and Repertory of Arts, &c. for August, 1851. "The principal apartment in the building [near Belfast] contains a number of large circular vats in which the flax is steeped, and these are provided with steam-pipes connected with the steam-engine boiler. The flax to be operated upon is placed in these vats, and filled up to a given height; strong cross-bars of wood, forming a kind of framework, are then laid above the flax and secured to the respective vats, the object of this framing being to keep the flax down in the vat, as otherwise it would rise as it swelled in fermenting, and protrude above the water. When a mass of flax is thus secured, water is run into the vat, and as it becomes absorbed, more is added. Steam is next admitted into and made to circulate through the steam-pipe at the bottom of the vat, so as to raise the water to about 90° Fahr., and maintain it at that temperature. In a few hours acetous fermentation is established in the vat, and the decomposition of the resinous or gummy matter in the stalk proceeds with rapidity. After about 60 hours the decomposition is completed, and that without the exudation of any odorous or noxious effluvium. The water surcharged with the mucilage is then drawn off, the framing is removeu, and the flax is taken out of the vat to be dried, either in the open air or by artificial means. . . . When the weather is favourable for drying in the open air, the flax, tied up in tufts or handfuls, is suspended in rows, tier above tier, in an open framing, covered in at top by a penthouse roof." In damp weather the flax is piled loosely in a drying chamber into which a current of heated air is passed, which quickly carries off the

moisture, the waste steam from the engine being economically used for heating the air.

Mr. Bower of Leeds has patented a process for improvements in *retting* flax. The patentee has found that by the ordinary method of water-retting a portion of the glutinous matter still adheres to the fibre, and renders it unfit for the scutching. By the improved process the flax is steeped in water, warm or cold, and after a few days (six, if cold water be used) taken out and passed between pressing rollers, for the purpose of expressing the glutinous matters from the interior of the plant. The steeping is then continued for a few days, when the rolling is repeated. The flax is then dried and treated in the ordinary way, when it will be found to be much clearer of the glutinous matter than if steeped in the ordinary way for a much longer time. For the finer descriptions of flax, the plant is steeped in a solution of caustic ammonia, common salt or Glauber salt. 1lb of caustic ammonia, or of any of the neutral salts, is added to every 150lbs. of rain-water, and with this solution, at any temperature from 90° to 120°, the operation will be completed in about 30 hours. A portion of one of these solutions will greatly assist the retting process first described.

Another improvement consists in operating upon the flax in a vessel exhausted of air; the flax being first steeped in water or in an alkaline solution, the air is exhausted, and the solution acts upon the flax so quickly and efficiently that two solutions and two exhaustions suffice to get rid of the glutinous matter in the course of a few hours.

Breaking and Scutching. Nothing now remains but to fit the flax for the market by separating it entirely from the wood. This is performed in Russia, Holland, and Belgium almost entirely by manual labour, employing a great number of persons. This is partially the case in Ireland; but machinery is also largely employed. The flax prepared by hand is first bruised in a machine called a *brake*, where two small rows of iron grooves, A, A, Fig. 938, meet on the flax, which is placed between them; so that each convex part of the upper row falls into the concave part of the under row, and bruises the wood without cutting or injuring the fibre. This is worked by the foot pressing upon a flat movable piece of wood, B, which is attached by

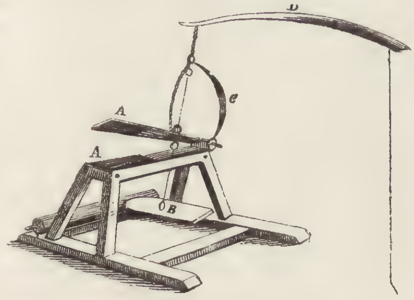


Fig. 938 THE BRAKE.

a chain or string to an iron spring, C, fixed at the extremity of the machine; or a spring-pole, D, will answer the same purpose, and give more power. After bruising in this machine, the woody part of the stem will separate freely from the fibre in the operation of scutching, leaving it in reeds. Scutching is performed with a broad flat blade of wood, Fig. 939, or Fig. 940,

Fig. 939.

Fig. 940.

Fig. 941.

Fig. 942.

held in the right hand, while with the left a handful of bruised flax stems is introduced into the groove B of the stand A, Fig. 942, and beaten with the scutch-blade so as to strike away the bits of woody matter. A buff-leather belt is stretched between the stand and an upright stake C, which is inserted into the flat bottom; and after the blade strikes the flax, it falls on and rebounds from the leather, which saves much fatigue to the worker. Any remaining bits of wood are cleared away with a broad blunt knife, Fig. 941, the flax being laid across the worker's leg, which is covered with a piece of leather, and scraped in that position. An active scutcher can turn out from eight to fourteen lbs. of clean flax in the day, provided it be well watered and in good condition.

The process by machinery is as follows:—

The retted and dried flax is carried to the rolling or crushing mill, and there passed by hand between rotating horizontal rollers which crack the boon, already loosened by the retting process, and spread or partially separate the long fibres. The flax as it is delivered out of the machine, is gathered up by boys and handed to others, who submit it by handfuls to the action of rotating knives. These knives are attached to the face of a vertical wheel, several of which are mounted on one and the same shaft, at about 3 feet apart, and receive motion from the engine. There is an attendant stationed at every wheel, whose duty it is to submit the flax to the action of the knives, by holding it over a fixed bar contiguous thereto, and allowing the rotating knives to strike the flax in the direction of its length. When the boon on one half length of the flax is broken away or knocked off, the flax is turned over and the other end is subjected to a similar treatment. Further to clean the flax of the woody particles, it is again submitted to a similar operation before another set of wheels, the action of the knives being in this instance more thorough and searching, as the flax has now approached nearer to a strick of fine fibres.

The accompanying figures will show the action of Mr. MacAdam's machinery.

The bruising is effected by metal-grooved rollers, four pair being necessary, fluted in different breadths. The flax is spread out on a flat table *a*, Fig. 943; the first pair of rollers taking it in, and passing it to the others in succession, when it issues completely bruised. The scutching is performed by a number of blades, *c*, of wood or iron, attached to arms, *d*, and carried round by a shaft, *e*, which is turned by the motive power. The flax is held by workers in a groove *f*, and the blades in revolving strike it quickly. The latter process is gone through three times, at different grooves, before the flax is considered finished. It is then ready for sale, and in this state it enters the flax-mill, to be acted upon by the *heckling* machine, for the removal of the tow or short staple, before undergoing the various operations of preparing and spinning to convert it into yarn. Flax is tied up in bundles of 16 or 24 lbs., the former termed the *English*, the latter the *Scotch stone.* These bundles are tied round with three or four bands, and, if well made up, can be tossed about without receiving any injury. The great markets for flax, to supply the spinning trade of the three kingdoms, are, respectively, Leeds, Belfast, and Dundee. There are commission-merchants in each, to whom flax may be sent for sale.

Two other methods of preparing flax are given by Mr. MacAdam in his valuable essay; one of which consists in drying the flax, after pulling, in stooks of a peculiar construction, then beating off the seeds, and steeping afterwards; the other, in drying as above, and then storing, the seed being beaten off during winter, and the flax not steeped till the following summer.

A patent has been taken out by Robert Plummer, Esq. of Newcastle-upon-Tyne, for several new implements and machines, for the more effectual dressing of flax. Last in the order of his inventions, but first as it respects actual use, is the *flax-breaking machine*, which is so contrived that the flutes on one roller do not quite touch those on another; hence the flax-straw in passing between them is less damaged, while, at the same time, it is more completely crushed and prepared than in any other machine. Figs. 946 and 947[1] give a back and side view of the flax-breaking machine, in which the rollers, five in number, are placed in two vertical series, one before the other, the front one of two rollers, the back one of three. The flax-straw, fed into the machine at *a*, passes between the top and middle rollers *b c* of the back series, and is directed downwards by the back plate *g*, so as to pass between the middle and bottom rollers *c d* of the same series, and it then passes through the two rollers *e f* of the front series. The rollers are all driven, and the ends of them have plain parts truly turned, which bear upon each other, so that the flutes of one roller work into the spaces of the next adjoining roller, and leave a space for the flax-straw to pass through; the rollers are weighted, and the pressure can be regulated as required.

In the scutching and preparation of flax for the spinning-mill, Mr. Plummer is of opinion that the machinery hitherto used for these processes has been applied on the principle of seeking to attain fineness, by reducing and destroying the character of the fibre, rather than on that of sustaining whilst cleaning it. Instead of the rigid tools to which it is usually submitted, he therefore applies brushes of whalebone, split into various degrees of fineness, bristles, or other

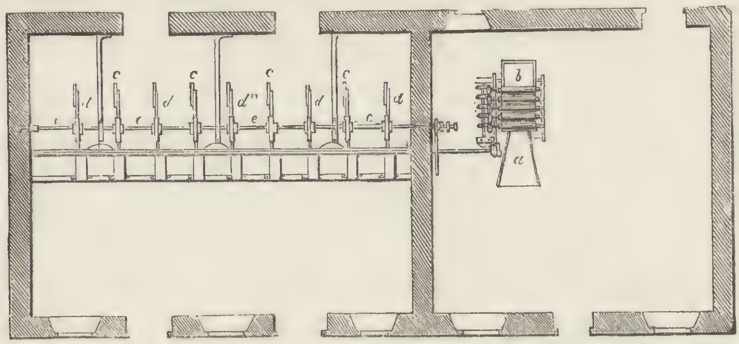


Fig. 943. PLAN OF MACADAM'S FLAX-ROLLING AND SCUTCHING MACHINERY.

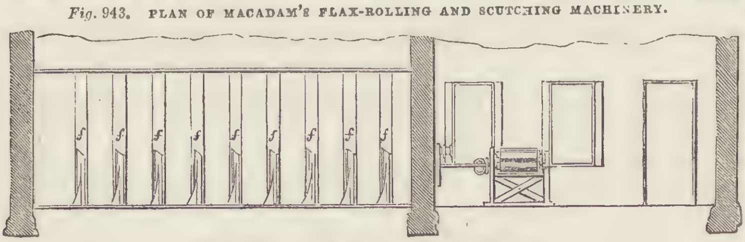


Fig. 944. FRONT ELEVATION OF THE SAME.

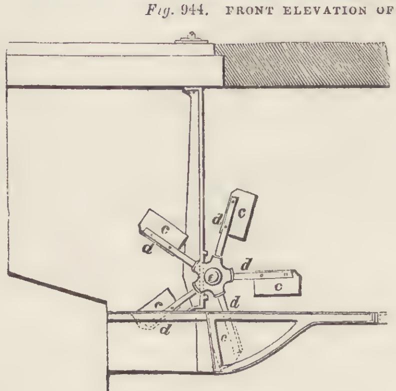
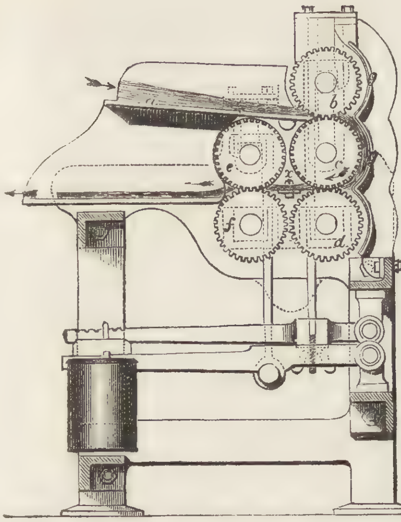


Fig. 945. END ELEVATION.

(1) In Fig. 947, the back plate for bending the straw downwards is not shown.



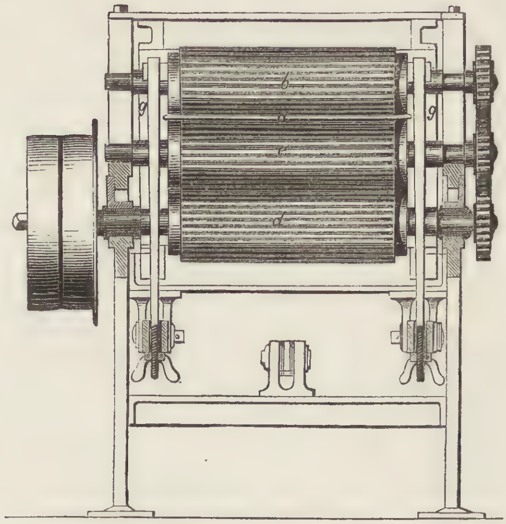


Fig. 946. *(Side View.)* PLUMMER'S FLAX-BREAKING MACHINE. *Fig.* 947. *(Back View.)*

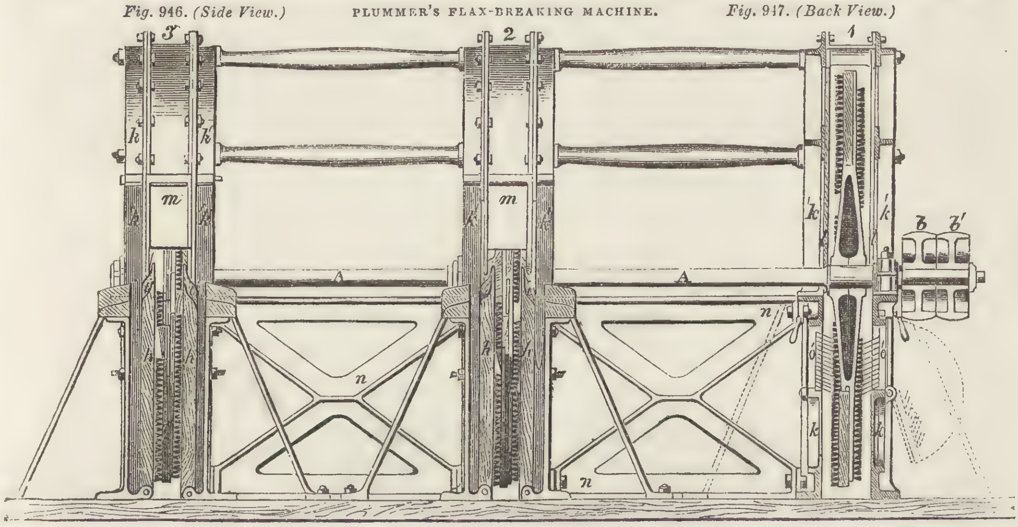


Fig. 948. FRONT ELEVATION OF ROTARY DISC SCUTCHING-MILL.

suitable materials, for nearly all the preparatory processes. The *rotary disc scutching mill* is intended to imitate more closely than has yet been done by machinery, the process of hand scutching in its pliant adaptation to the varying quality and conditions of the material to be scutched. Fig. 948 is a front elevation of this machine; and figs. 949, 950, represent one of the forms of scutching discs with the brushes fitted to it. A, fig 948, is an axle with its bearings in an independent metal framing, $k\,k^1$, (the upper portion being made to open,) with a lining of deals, *l l;* the metal piece *m m* at the front end, being secured by three bolts, can be easily removed for the purpose of changing the brushes in the discs. The framing is stiffened by cross pieces, *n n*, at the back end by three long bolts, and metal ferules or pipes between each stand and portion of the frame, and the whole is screwed together by nuts at each end of the bolts. A free space is left at the back end of the casing, to allow the air to be thrown off, and at the top the space is

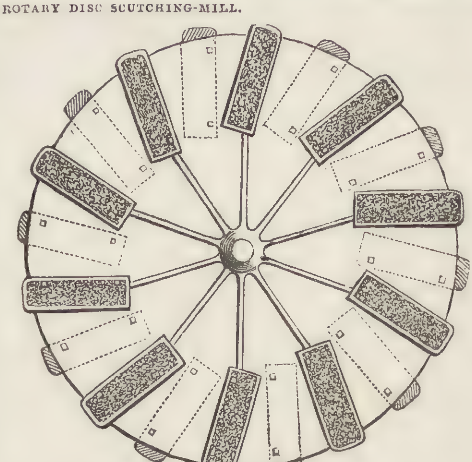


Fig. 949. SCUTCHING DISC.

Fig. 950. SECTION OF SCUTCHING DISC.

contracted, to prevent, as much as possible, the air from being carried round in the same direction with the disc. The back end of the disc casing may be connected with an exhaust pipe, to carry off the dust from each stand. The axles A, are moved by a band passing over the pulley b (b' being loose). In the ordinary scutching machines this axle carries a number of radial arms, with naked knives or blades attached to them, as in fig. 943. For these arms Mr. Plummer substitutes the disc, fig. 949, with sets of brushes fixed either to one side or to both sides of the disc, as in fig. 950, in which latter case each disc has two stands, as in fig. 948. The disc form is better than that of radial arms, as in the ordinary scutching mill, because these arms in their revolution produce cross currents of air, and cause the flax to rise from the scutching board and curl round the edges of the knives or blades, to the great damage of the staple. The brushes may be attached to the discs at any or various angles of inclination, by means of a spring catch, so that they can be readily taken out or put in, or changed from one side of the disc to the other. The outer ends of the brushes wear more rapidly than the inner, or those nearer the centre of the disc, and they are so made that the ends may be changed, and thus both ends be equally worn before the brush need be renewed. The top, i, of the scutching board, h, on which the flax to be scutched is laid, is placed a little above the centre of the axle A, so that a straight line, z, drawn from the centre of the axle, would intersect the middle of the top line of the scutching board, or nearly so, instead of passing below it, as would be the case were the scutching board placed as usual, and as is indicated by the dotted line j. The comb o^1 is of steel wire, and is used to clear the brushes of any fibres adhering to them: the points of the comb may reach only to the face of the brushes, or may penetrate a short way into the brushes: the back of the comb is fixed to a door formed of a plate of iron, turning on a hinge, and secured by a catch with a handle, so that at any time the heckle may be readily cleared without stoppage to the machine. The comb may be fixed to any convenient part of the framing, and at any required angle.

The flax, while being scutched, is held in a holder instead of in the hand, as in the ordinary mills. By this means it is more fully and evenly spread out, and more thoroughly acted on by the brushes.

Mr. Plummer has also invented a *double cylinder brushing machine*, of which fig. 951 is a side elevation, and fig. 952 an end view. In these a a

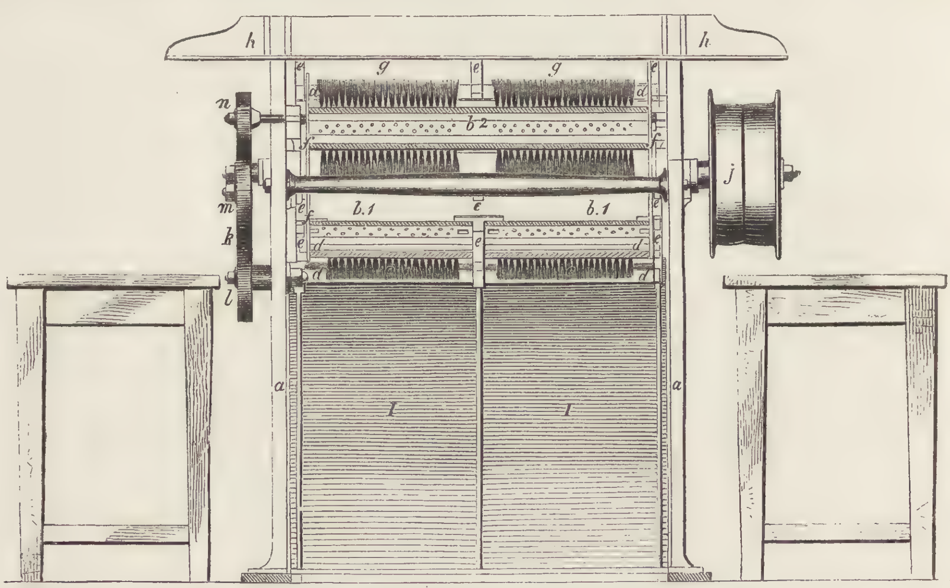


Fig. 951. SIDE ELEVATION OF PLUMMER'S FLAX-BRUSHING MACHINE.

is the frame-work, b^1 b^1 are two cylinders, each of which revolves inwardly upon an axis; c c are sets of brushes affixed to the peripheries of the cylinders, so that the sets of brushes of the one cylinder shall take into the vertical intervals of the sets of the other cylinder, and thus give at one and the same time a front and a back stroke to the streaks of flax let in between them: d, d, are the stripping-bars, which extend along the whole length of each cylinder, and rest freely in slotted bearings e e; ff are semicircular guards, which, during a little more than half of each revolution of the cylinders b^1 b^1, confine the stripping-bars to the inner ends of their slotted bearings, and thereby regulate, as usual, the depth to which the brushes or heckles shall penetrate the streaks, but after passing a line drawn horizontally through the centres of the cylinders, allow the bars to strike out to the full extent of their slotted bearings, and thereby to doff and throw down the tow left adhering to the brushes which have just been in action: b^2 b^2 are two smaller revolving cylinders, which are fitted with rows of brushes g, g, of a

similar elastic description to *c*, *c*, and so placed in respect of the larger cylinders $b^1\ b^1$, that the brushes *g*, *g*, shall, as they revolve, come in contact with, and free the working brushes *c*, *c* from any shive or dirt which may gather upon them, or from any fibres which the stripping bars may not have sufficed to throw down; *h h* is the trough bolted to the framework *a a*, for carrying the holders which contain the streaks, and *I I* is an inclined grating for receiving the tow, as it is doffed or thrown down by the stripping-bars from the brushes, and precipitated downwards. Motion is given to the different parts of the machine, from any first mover, by means of pulleys or sheaves *j*, *j*, attached to the axle of one of the cylinders b^1, and by the wheel gearing in connexion therewith, marked *k*, k^1, *l*, l^1, *m*, m^1, and *n*, n^1, the relative number of revolutions so adjusted that the brushes *g*, *g*, shall revolve at twice the speed of the brushes *c*, *c*.

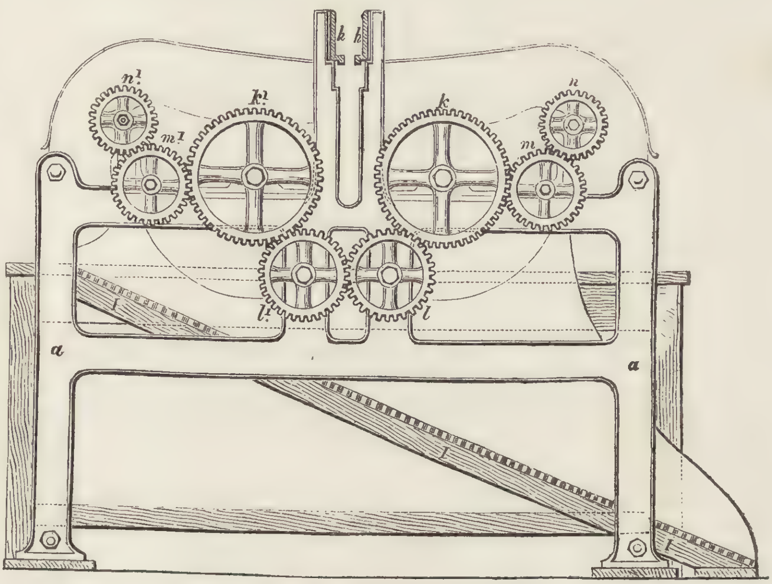


Fig. 952. END VIEW OF BRUSHING MACHINE.

DIVIDING INTO LENGTHS. By the operation of *scutching*, the flax is freed from all its woody particles, and is ready for the flax mill, where it is converted into linen yarn. The length of the staple in flax varies from 26 to 30 or 36 inches. The part nearest the root is coarse and strong, the middle part fine and strong, and the upper part fine but not so strong. The flax is therefore divided into three lengths, and the parts from the bottom, middle, and top, being collected into separate heaps or *stricks*, several qualities of thread are afterwards formed from them. Occasionally the flax is divided into four or five lengths, instead of three, but in either case the division must be made by a tearing of the filaments instead of cutting them, as the latter would unfit them for spinning. An ingenious machine is therefore in use for effecting this in a regular manner. It consists of a number of upright wheels, and a centre wheel furnished with oval teeth. A boy, holding a handful of flax at both ends, passes it between two side wheels, which hold it securely while the centre wheel tears it across. The latter moves with great rapidity, while the holding wheels move slowly, so that the dividing wheel has time to do its work before the flax escapes from the pressure of the holding wheels.

Mr. Plummer deprecates the plan of cutting up the flax into lengths, and maintains that if a long and generous fibre be treated with gentleness instead of harshness, a considerable saving may be effected, and many advantages must accrue to the manufacturer.

HECKLING is the next operation, by which the flax is cleaned, split, and separated into fibres in parallel order, while the coarser matter is removed. The *heckle*, or *hackle*, is a sort of comb, the teeth of which are usually of iron or steel, from one to two inches in length, and very sharp at the points, which are sometimes four-sided instead of round, for the better separation of the fibres. They are arranged on an equal level, being passed through holes in a brass or iron plate, which is fixed to a square or circular block of wood, rising from an oblong plank. Two or more heckles, of different degrees of fineness, may be mounted side by side on one plank; the finest may perhaps contain upwards of a thousand teeth. In heckling, the workman seizes a lock of flax by the middle, throws it upon the points of the coarse heckle, and draws it towards him; at the same time, with the other hand, spreading the flax, and preventing it from sinking too deeply among the teeth. In this way the flax is divided into two parts, the short fibre or *tow*, and the long fibre or *line*. One-half the length being heckled, the other half is turned round and prepared in a similar way. The process is then repeated on the fine heckle, until the required fibre is produced. One hundred pounds of well-cleaned flax is reckoned to yield from forty-five to sixty pounds of line, the rest being tow, boony particles, and dust. An unskilful heckler produces more tow than flax, but a good heckler throws the flax more or less deep among the teeth according to circumstances, and exercises the force and dexterity which are necessary to separate it into fine parallel lines. Sometimes between the first and second hecklings, the flax is folded up in a bundle, and beaten upon a block with a wooden mallet, after which it is well rubbed with

the hands. The sort of assistance thus given to the heckler may be gained also by bruising the flax upon a board with a stiff brush, and also by boiling in potash-lye.

Heckling by machinery is generally practised in large mills. The flax being divided into lengths of about 10 or 12 inches, a certain quantity is taken, spread out, and fixed in an iron vice or holder, Fig. 953.

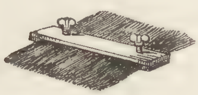


Fig. 953.

A number of these are then conveyed to a sort of revolving drum, and hooked on at distances of a few inches from each other; their unsupported ends falling on an internal drum covered with sharp heckling teeth, and revolving with considerable velocity, and in a contrary direction to the outer one, the motion of which is rather slow. When one machine has done its work, the holder is thrown off upon a rail, from which the *machine-minder* removes it to the second heckling machine, where the other side of the strick is heckled; thence to a third, and so on, until the proper fineness is obtained. In some machines the lower ends of the flax in each strick are first acted on, and, as the strick advances, the middle part, and lastly, the whole length of the hanging fibres are gradually brought on to the heckles, and both sides of the strick heckled at the same time. By this method the long fibres are not broken, and a smaller quantity of tow is produced. The holders are then returned to the children to be opened, the stricks of flax are taken out and replaced in an inverted position, and passed through the heckling

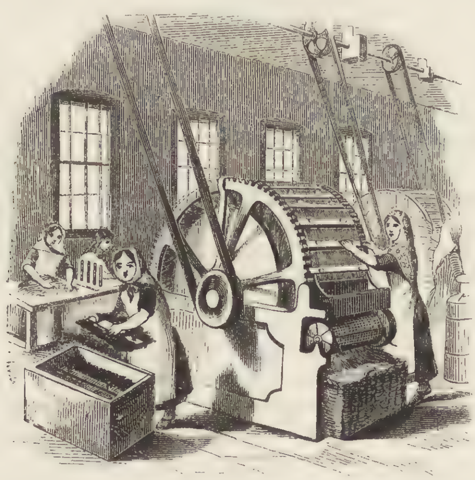


Fig. 954. HECKLING-MACHINES.

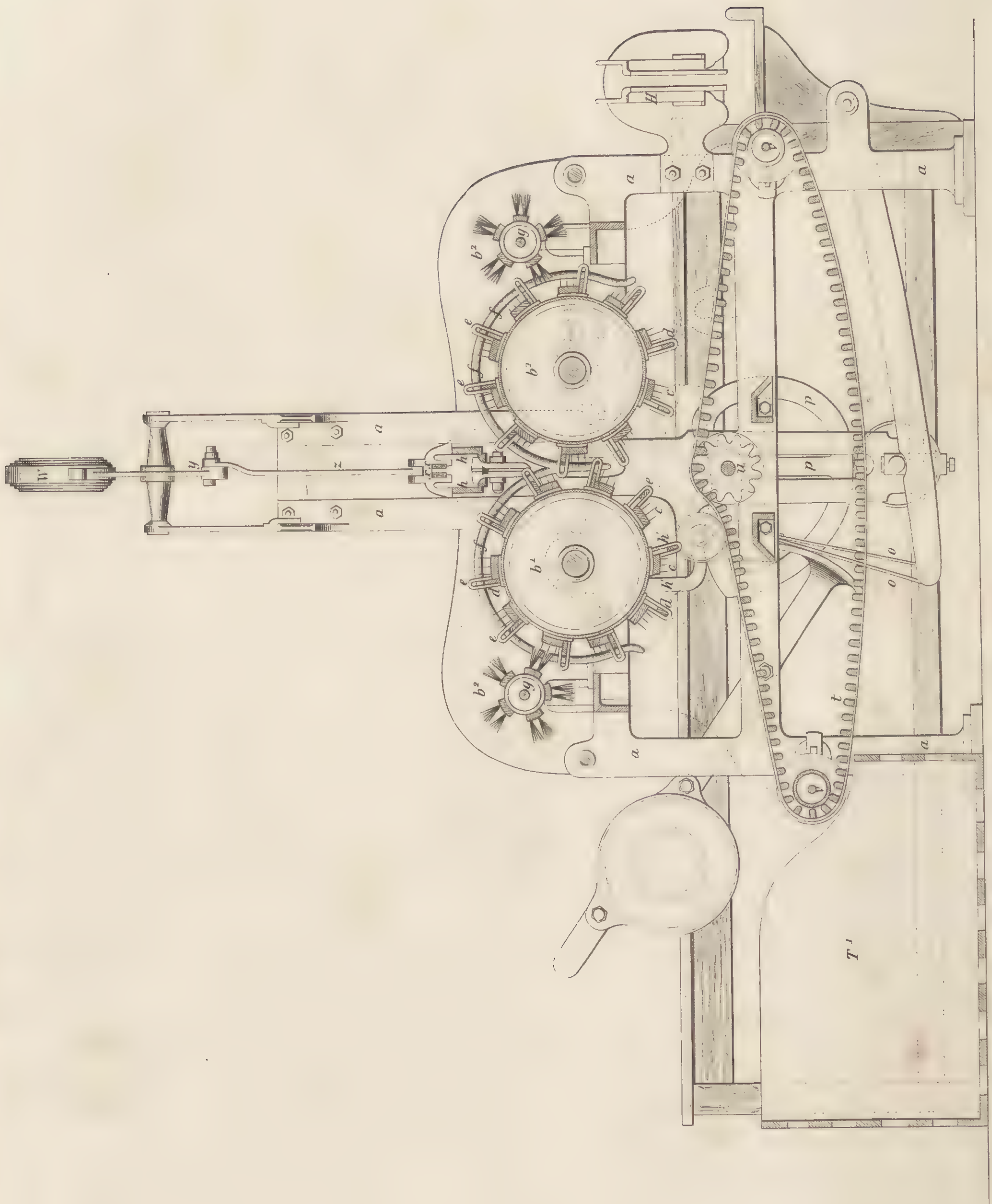
machines as before. Fig. 954 gives a view of this machine, and the appearance of the girls at work.[1]

The heckled flax is greatly improved in appearance: the line consists of long, fine, soft, glistening fibres, of a bright silver-grey or yellowish colour. This alteration is due to the splitting of the fibres by the sharp points, as also to the getting rid of dirt and dust, but chiefly to the removal of the short loose fibres, or tow, of which the larger portion is obtained from the upper part of the original length. A large quantity of the dust escapes into the room; the remainder gets entangled with the tow, which must be removed, or it would soon choke up the spaces between the heckle points and prevent their further action: a series of brushes fixed upon wooden cylinders are, therefore, made to revolve while the machine is in action; the bristles, passing between the points of the heckles, remove the tow or other loose matter therefrom.

Tow, being similar to cotton in its fibre, cotton machinery, in a modified form, has been applied to spin it. The tow is therefore transferred from the brushes to a revolving drum covered with cards, as in the cotton carding-engine, from which it is taken off by a comb moved by a crank: it is carded a second time, and formed into a continuous sliver: this is transferred to the drawing-frame, and extended by means of rollers in the usual way, the fibres being laid parallel by means of a series of gills or heckling-points. The slivers, being properly doubled and drawn, are formed into rovings, and then wound upon bobbins, after which they are spun into a fine, but not very strong thread.

In heckling machines, Mr. Plummer also comes forward as an improver. We have already seen that instead of first employing the rigid tools used in heckling, he subjects the flax to his *brushing machine*, where brushes made of elastic materials act gently on the fibre, and produce a cleaner and brighter state of the flax, with less waste. In the *heckling machines*, to which the flax is then removed, brushes are again substituted to a great extent. Mr. Plummer's inventions in heckling machines comprise a *double-cylinder machine*, best adapted for cut flax, and an *oscillatory double sheet machine* for long flax, in both of which brushes unite with heckles to produce the desired effect. The advantage of *double* machines is, that they dress both sides of the flax, and thus double the quantity of work is obtained. In the first place, both sides of the flax are brushed before meeting the heckling points or pins, by which means crossed or entangled fibres are got rid of. Improved holders are also introduced, which spread out the flax better and expose it more regularly to the brushes and points. The brushes and pins are made to work close up to the holder, and the opposing set of pins is made to intersect and strike the flax so as not to injure the fibre. By this means more line and less tow is produced, and both are freed from shive and

1) The sketch for this engraving was taken in Messrs. Marshall's mill, at Leeds. The Editor remarks, in his work on the Useful Arts, already quoted: "The operations of dividing and heckling the flax, which are performed in the same room, occasion rather a dense cloud of dust and loose particles. The girls protect their hair from this dust by wearing a handkerchief tied across the head, and hanging loosely down the back; this also protects the neck and shoulders, and has a not unpleasing effect. From habit, this head-dress is constantly worn in or out of the factory, serving the purpose of a bonnet, except on Sundays. The writer noticed this habit in Yorkshire only, and not in the cotton-mills of Lancashire, where it would seem to be equally necessary and useful.



dirt. The tow is also delivered without the usual doffing apparatus.

The steel engraving, and Fig. 955, represent a side and end elevation of the double cylinder heckling machine, adapted to the dressing of cut or short flax. There are two revolving cylinders, $b^1 b^1$, mounted in a frame-work *a, a;* attached to their peripheries are sets of rigid heckles, *c′*, intermixed with the sets of elastic brushes *c c*, (in any way that may be deemed most advisable.) The cylinders are also made to revolve inwardly, or in opposite directions, and the rows of brushes and heckles on the one cylinder are placed in an alternating order in regard to those of the other cylinder. There are also loose stripping bars with guards, that, besides regulating the depth to which the heckles or brushes shall

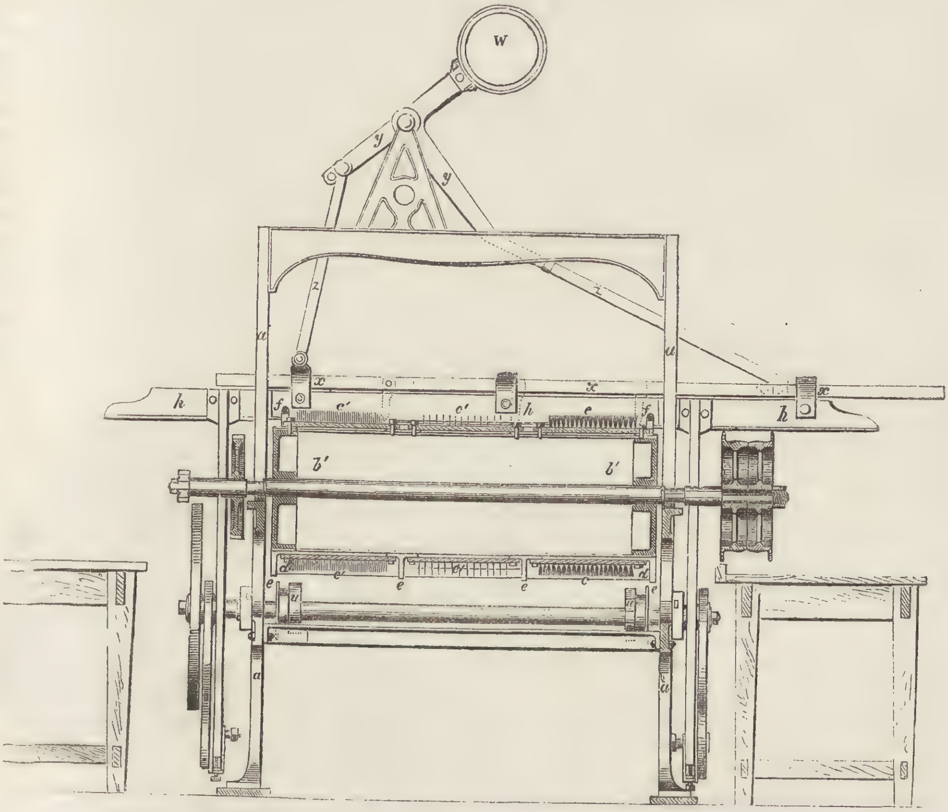


Fig. 955. LONGITUDINAL SECTION OF PLUMMER'S DOUBLE CYLINDER HECKLING MACHINE.

penetrate, doff or throw down the tow from the brushes and heckles, and two smaller cylinders b^2, b^2, fitted with brushes, for cleaning the working brushes and heckles *c, c′*. One of the cylinders b^1, may, if required, be made to oscillate by means of the link h^1, h^1, which, as it rises and falls with the lifter to which it is attached, moves the cylinder in a horizontal direction to and from the other cylinder; the bearings of the oscillating cylinder being made to slide, and attached by a rod to the radius arm to which the stud-pin of the wheel m^1 is fixed, the whole of the wheels k^3, l^1, m^1, and n^1 are thus kept in gear, to answer the varying positions of the oscillating cylinder. Rotation is given to the rotating parts of this machine, as in the one first described, but the holder is made to traverse or move forward in the trough (which movement may also be applied to the brushing machine), by the combination of a rack or of a bell-crank movement with the rising and falling motion of the trough, as afterwards described. The mechanism for lifting the trough *h* is partly shown in Fig. 955: it consists of a combination of pinions, wheels, a cam, straps, pulleys, and levers such as is ordinarily used in heckling machines. When the trough is raised, it pushes up a rod *x*, Fig. 955, which is connected to the long arm of the bell-crank *y*, mounted on a standard affixed to the top of the frame-work *a*, when a weight W, which is attached to the opposite end of the arm, falls over, and causes the short arm of the bell-crank to pull in a rod *z i*, which draws forward a finger bar *x*, (of the ordinary construction,) to an extent sufficient to advance the holder the breadth of one set of heckles or brushes. The tow and shive or dirt doffed or thrown down from the heckles or brushes is in this case received upon an endless chain of bars *t, t,* which extend the whole length of the machines under the heckles and brushes, and are connected together by two side bands. The chain of bars revolves round two friction pulleys v v, and takes into two pinions *u*, (one on each side); by means of pinions, rotation is given to the chain from the

same first mover by which the other parts of the machine are put in motion. The shive or dirt falls through between the bars on to the floor, while the tow is carried forward on the top of the bars and delivered into the trough T^1. To separate the tow doffed from each set of heckles or brushes, the space between the endless chain of bars and the cylinders is divided by partitions into as many compartments as there are sets of heckles or brushes, and the receiving trough T^1, is also divided into a corresponding number of compartments.

A view of the holder for this machine is given in Fig. 956, a cross section, and Fig. 957, a longitudinal

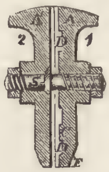


Fig. 956.

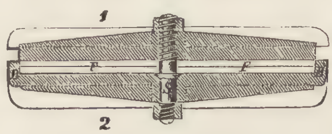


Fig. 957.

section. It consists of two plates, Nos. 1 and 2, connected transversely by a screw-bolt s, and having flanges A, A, at their upper edges, by means of which they are supported in the trough *h*. The plate No. 2 has two flanges B, B, one on each end, which come within the two flanges A, A, of the plate No. 1, and thereby confine the streak at the edges. The inner face of the plate No. 2 is planed perfectly true, and covered with felt, cloth, or some other soft or yielding material; but the plate No. 1 is made, on its inner face, with flat beads C, and flat grooves D, in alternate order, so that the streak of flax or other material may be more firmly compressed between the plates without being unduly crimped. At their under edges E, the plates are chamfered off to admit of the holder coming lower down. By this mode of construction, the pins or studs ordinarily made use of, to confine the outer edges of the streaks, are dispensed with, and a greater breadth is obtained whereon to spread the streaks, and the holder is also narrowed and rendered more easy to work.

Sorting.—The heckled flax or *line* is sorted preparatory to drawing and roving. Sorting is an operation in which the sense of feeling is cultivated to a remarkable extent, the *line-sorter* judging of the various degrees of fineness by the touch rather than by the eye, and by this means separating the stricks of heckled flax into several divisions according to their fineness. The line-sorter seats himself before a *sorting-box*, which is a kind of table containing several boxes or divisions for receiving the various qualities of line, which are called 2lbs., 3lbs., 3½lbs., 4lbs., 5lbs., 5¾lbs., 6½lbs., &c., from an old method of comparing fineness and weight, which will be further noticed under *Reeling*. In the course of sorting, the line is frequently drawn through a block heckle, in order to keep the fibres parallel. The tow is also sorted into qualities preparatory to spinning.

Spreading, drawing, and roving.—The sorted line is next converted into ribands or slivers. For this purpose it is spread upon a feeding cloth in such a manner that the ends of the second strick reach the middle of the first. In this way a uniform thickness is preserved, since the heckled stricks are thicker in the middle than at the ends. The flax is then passed between one pair of rollers, which deliver it through gills or heckling points to a second pair, which, moving with much greater speed than the first, increase the length and diminish the thickness of the flax. During this operation the flax receives no twist, but is converted into a flat narrow tape or riband, which is received into a tin can. When the can is full it is taken to a drawing or *spreading* frame, where a number of slivers are united and drawn into one length. Three sets of these frames are often used, and when the writer inspected the processes at Messrs. Marshall's mill, 8 slivers were drawn into 1 at the first frame; 12 into 1 at the second, and 15 into 1 at the third. The frames are attended by young women, each of whom has the charge of four.

The slivers next go to the roving frame, where they receive a slight degree of twist and are wound upon bobbins preparatory to spinning.

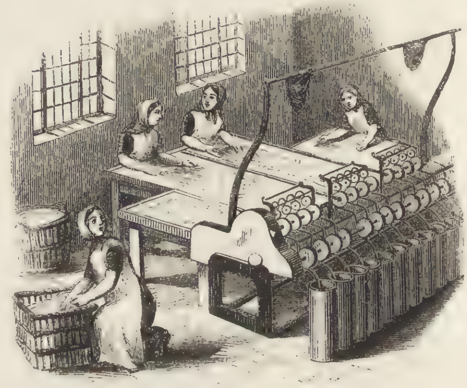


Fig. 958. SPREADING FRAME.

Spinning.—The extension of the factory system has had the effect of banishing the flax and cotton spinning wheel, as well as the hand loom, from the cottage of the weaver. During many centuries the production of linen in Ireland was so common that it was almost regarded as the national manufacture. Before the establishment of factories "the spinning of yarn by hand was the ordinary occupation of the females of almost every family in the province of Ulster connected with the linen weaving. It was a constant source not only of employment, but of fair, and sometimes even liberal profit, and of a nature eminently adapted to the social and physical capabilities of those who followed it."[1] The substitution of mill-spun yarn for the hand-spun has superseded the domestic spinner and weaver.

The spinning of flax differs little from the throstle-spinning of cotton, [see Cotton, page 465,] but the fibres of flax have not the same tendency to entangle themselves together as those of cotton, therefore it is

(1) Report of R. M. Muggeridge, Esq., on the Linen Manufactures of Ireland.

necessary to moisten them with water to make them adhere to each other, and also to make them more pliable and easy to twist.[1] Until recently, the flax for machine-spinning was moistened with cold water, but a great improvement has been effected by substituting water at the temperature of 120°, which allows a much finer and more uniform thread to be spun, and double the length to be obtained from a given weight of flax. The warm water is contained in a trough, which extends the whole length of the spinning frame, and the rapid motion of the spindle causes a dewy spray to be continually thrown off. A great inconvenience was for a time experienced by the attendants, whose clothes were completely wetted in an hour or two by this minute spray, but the use of water-proof aprons has been found a sufficient remedy. This operation, however, produces a hot steaming atmosphere, which is painful to casual visitors of a flax mill, though not unpleasant to the operatives.

The yarn, by doubling, is made into linen thread, which is bleached and formed into balls or reels. The yarn itself is wound upon reels, and then made up into leas, hanks, bundles, &c., as in the following invoice.

TWO AND A HALF YARD REEL.

120 Threads of $2\frac{1}{2}$ yards.........	300 yards or 1 lea.
10 Leas................................	3,000 yards or 1 hank.
20 Hanks..............................	60,000 yards or 1 bundle.

(Three bundles are usually put together in one bunch)

ONE AND A HALF YARD REEL.

100 Threads of $1\frac{1}{2}$ yard	150 yards or half a lea.
10 Half leas..........................	1,500 yards or 1 hank.
40 Hanks..............................	60,000 yards or 1 bundle.

(Six bundles are usually put together in one bunch.)

The fineness of linen yarn is reckoned by the number of leas to the pound weight. In 1839 the common limit of fineness of linen yarn spun by machinery was about 150 leas, and this was all used for different descriptions of common linens, not being sufficiently fine for the manufacture of fine cambric or of lace; but yarns from this limit up to 240 leas were spun by machinery, for the manufacture of Irish lawns and coarse cambrics. At the same time yarns of from 300 to 400 leas were spun by hand.

In sorting line, the various qualities are divided into 2, 3, $3\frac{1}{2}$ pounds, &c., as above mentioned. In linen yarns, the bundle of 60,000 yards is sometimes called by its number of leas per lb., or by the weight of the bundle. Thus a bundle of 25 leas to the lb. weighs 8 lbs.; a bundle of 50 leas to the lb. weighs 4 lbs.; a bundle of 100 leas to the lb. weighs 2 lbs.; so that 8 lbs. and 25 leas, and 4 lbs. and 50 leas, and 2 lbs. and 100 leas, are synonymous terms, as far as the size is concerned. In sorting, a certain quality of line will spin to a certain size or weight per bundle, and it was formerly the custom of line-sorters to call certain qualities 2 lbs., 3 lbs., $3\frac{1}{2}$ lbs., 4 lbs., &c., because that quality of line would spin to that weight per bundle. The same standard and name are still retained by line-sorters for the same quality of line, but from improvements in machinery, and other causes, $5\frac{3}{4}$-line can now be spun to the size of 3 lbs. the bundle, and even finer.

(1) For coarse purposes, flax can be spun dry, and is so to a great extent in the Scotch factories.

STATISTICS. So long as the production of linen yarn was confined to the spinning-wheel, linen was a costly article, and the trade necessarily limited. The powerful effects upon the wealth and industry of the country, by the introduction of cotton machinery, was soon extended to flax. Mr. Marshall states that "before flax was spun by machinery, the French and Belgian spinners were so superior to anything that we had in this country, or in Ireland, that the linens were a great part of them imported from Flanders, or from the north of Europe."

Mills for spinning flax were first constructed at Darlington, about sixty years ago, and the improvements which have been made in spinning and in bleaching, &c., have raised the British trade to the same level, and even above that of foreigners; so that besides supplying our own markets, we export largely. Our exports of linen yarn, however, have of late years been subject to considerable fluctuations. Thus in 1848 they were of the declared value of 493,449*l.*; in 1849, 737,650*l.*; in 1850, 887,295*l.* To some countries, France for example, our exports have gone on gradually declining in consequence of the success of native manufactures. In 1841 France took 20,832,875 lbs. of our linen yarn; in 1850, only 690,602 lbs.

In 1849 there were imported into the United Kingdom, of flax and tow, or cordilla of hemp and flax, 1,806,786 cwt.; and in 1850, 1,821,578 cwt.

The principal flax mills in England are in the West Riding of Yorkshire, and its immediate vicinity, and in Lancashire, Dorset, Durham, and Salop. In Scotland, Dundee is the chief seat of this trade; and in Ireland, Belfast. Some years ago Mr. Marshall stated that the linen trade had doubled in England, and trebled in Scotland, within half a century; and that the improvements in machinery had been such, that in order to keep pace with them he had re-constructed his mill twice within that period. This must have been a costly proceeding, since the number of persons employed by him amounts to above 2,000.

Fig. 959. THE ROOF OF MARSHALL'S ONE-STORY FLAX-MILL.

Fig. 959 is the appearance of the roof of Marshall's one-storied flax mill, a description of which is given in the article FACTORY.

FLAX, COTTONISING OF. An interesting discovery has been made by a gentleman, formerly an extensive cotton-grower and slave-owner in the Brazils, by name the Chevalier Claussen. This is no other than that flax may be employed to a great extent in the same way as cotton, and may be adapted for mixing with wool. The important results that are likely to flow from this discovery, with the prospect of a new market for home-grown flax, make it desirable to give the details of the origin of the idea. The chevalier, it appears, was wandering along the luxuriant banks of one of the Brazilian rivers, when his attention was arrested by a white downy substance adhering to the branches of trees overhanging and touching the stream. Thinking that he had discovered some hitherto unknown vegetable substance, he collected a quantity of it, and endeavoured to ascertain whence it came. At last he traced it, not to some new plant or shrub, as he had expected, but to his own bed of flax-straw, which, long before, had been thrown as refuse on the banks of the river. To this heap the swollen waters had occasional access; fermentation, and decomposition of a portion of the plant had taken place, and, in time, the influence of natural chemistry had so separated the filaments of the flax fibre as to give the mass a cotton-like appearance; and some of it, having been washed into the river, had been arrested by the overhanging branches. Although the substance thus accidentally discovered was far from being in the state which would fit it for the hands of the cotton-spinner, yet, even in its then imperfect condition, it led the chevalier to entertain the idea of completing, by the aid of chemistry, that which nature had partly accomplished.

M. Claussen accordingly set on foot a series of experiments, which have led to remarkable results. He has cleared away difficulties that have long been felt in every stage of the preparation of flax, and has proved that the *cottonising* process may be carried on successfully in this country. It has been known for some years that the fibre of the flax is separable from the straw without steeping, and any one rubbing a ripe stalk of flax between his fingers, may find that a partial separation takes place in his hand. But it was for Claussen to turn this knowledge to practical account by constructing a machine which should enable the grower to effect this desirable separation, and thus reduce the bulk of a crop which previously had either to be taken to market as it was grown, or to be subjected to troublesome and expensive processes. This machine does little more than separate the straw, the fibres being still partially held together by the gum-resin. But even now, the flax is in a state which makes it suitable for strong and coarse fabrics, such as sail-cloth, ropes, cordage, canvas, &c., and it may be profitably applied to many of these uses as a substitute for Russian hemp. In order to fit it for the linen manufacturer, and also for the cottonising process, a more complete separation of the fibres must be attained by steeping. But this, according to the existing plan, occupied too much time, and also was not sufficiently uniform in its action to satisfy Claussen. He therefore adopted the plan of boiling the flax for about six hours in a weak solution of caustic soda, or if time could be allowed the solution was heated to about 150°, and the steeping continued for twelve hours. Caustic potash or lime may be used instead of soda. This completely dissolved the resinous and oily substances of the plant, producing a soapy kind of liquid, which removed at the same time all extraneous matter, leaving it, unlike flax steeped by the ordinary method, perfectly free from stain and impurity. By this valuable method, the preparation of long fibre is not only effected in one day, instead of perhaps a dozen, but it is also uniform in strength, and can be bleached and dyed with much less trouble.

If the fibre is required to be *long*, such as is now commonly spun in flax machinery, the free alkali adhering to the fibre is got rid of, together with any remaining gummy matter, by steeping it for about 2 hours in water acidulated with sulphuric acid, or instead of this, the wet flax is exposed to the fumes of burning sulphur. The acid combines with the alkali, forming a sulphite or a sulphate, according to the acid employed. The flax is next washed in water, and then bleached.

In the bleaching process, a great portion of the chlorine or chloro-compound is kept in a combined state, and reserved for future use. The goods, after having been passed through the bleaching liquor, (such as a solution of hypochlorite of lime,) are steeped in a strong solution of some salt whose acid has a more powerful affinity for lime than the hypochlorous acid. Thus a strong solution of sulphate of magnesia may be employed, the sulphuric acid of which, having a strong affinity for lime, combines with the earthy base of the bleaching salt, and forms sulphate of lime, and the chloro-compound being thus liberated, unites with the magnesia of the sulphate of magnesia and forms a new salt, hypochlorite of magnesia, having bleaching properties similar to the lime salt first employed This newly-formed compound may be, in the next instance, used as a primary bleaching agent, and may again be subjected to the process of double decomposition as in the foregoing example. The advantage of this method is, that the chlorine, instead of escaping, or remaining long enough in contact with the goods to injure them, is made to form a new salt, having bleaching properties. By another method of bleaching, the goods are exposed to the fumes of burning sulphur while still wet with the solution of bleaching liquor, such as hypochlorite of lime. A portion of the sulphurous acid (itself a bleaching agent) combines with the base of the chloro-compound salt to form a sulphate of lime; and in this way the chlorine remaining in the wetted goods is liberated, and allowed to act freely upon the articles to be bleached.

The flax, being washed and dried, is ready for

breaking and scutching, as in the ordinary manufacture of long flax. It is, however, advantageous to pass the straw between rollers, so as partially to break it, before submitting it to the action of the chemical agents above noticed.

If the fibre is required to be short, so that it may be felted or carded, and adapted for spinning on cotton, silk, wool, worsted, or tow spinning machinery, several additional processes are required. First, by a nicely adjusted machine, similar in operation to an ordinary chaff-cutter, the flax is cut into short lengths, corresponding with the staple of cotton. Next, by an ingenious application of chemical forces, the harsh and elastic fibres of the flax are brought to the soft and downy texture of cotton, thus overcoming a difficulty which seemed for ever to preclude the possibility of spinning flax upon cotton machinery. The fibres of the flax, under the microscope, present the appearance of small bundles of minute hair-like substances, and it was this fact which led Claussen to seek some further mode of subdivision beyond any that mechanical means could furnish. It has been already stated that, instead of steeping in the ordinary way, he boils his flax in a solution of caustic soda. The flax to be cottonised, when taken out of the soda vat, is placed in another containing a solution of bicarbonate or sesquicarbonate of soda, in which it remains three or four hours till fully saturated with the salt. It is then placed in a third vat, containing a weak solution of sulphuric or other acid. The hollow cylinders of the fibres then become charged with the acid solution, which, coming in contact with the salt which the fibres had taken up before, generates carbonic acid gas, the expansive force of which splits the fibres into a vast number of ribbon-like filaments, which under the microscope present the appearance of raw cotton. Thus, in a moment, and as if by enchantment, all those minute hair-like fibres are released, and the whole becomes a soft and cottony mass. This flax-cotton, when dried, carded, and spun, will be found to produce a considerably greater quantity of yarn than that obtained from a similar weight of cotton: and so well adapted is this new substance to cotton machinery, that several large manufacturers have expressed their willingness to take any quantity that may be supplied to them. These yarns mix well with cotton, wool and silk, and dye extremely well. By the mixture of flax-cotton with wool it is expected that cloths quite as durable as those made of wool alone, will now be produced at a lower price. Claussen's own estimate of the price at which flax-cotton can be produced is as follows:—"On the average, five tons of flax-straw will produce one ton of British cotton, the cost of which, at 3*l.* per ton, would be 15*l.* The expenses of breaking, cutting, and blowing will not exceed 1*l.* 19*s.*; chemical preparations and ingredients employed, 1*l.* 5*s.* Thus the total cost of one ton of flax fibre, or British cotton, equal to fair quality American cotton, would be 18*l.* 4*s.* Add to this, where required, the bleaching, 1*l.*, and the washing, drying, &c. 1*l.* 16*s.*; then the total cost of the British cotton, bleached and washed, would be 21*l.* per ton, or 2¼*d.* per pound, and which will readily sell at from 4*d.* to 6*d.* per pound." The average price of foreign cotton for ten years, from 1835 to 1845, at Liverpool, was, Upland American cotton, 6½*d.* per pound; Surat and Madras cotton, about 5*d.* If the above estimate of results by Claussen can be fully carried out when the experiment comes to be tried on a large scale, there is very little doubt of the progress of flax cultivation in Britain. Our agriculturists would indeed be blind to their own interests not to give their best attention to this subject, which is already exciting the interest of several foreign countries.

An experienced flax-grower in Gloucestershire, Mr. R. Browne, in common with some other agriculturists, believes that the flax fibre is materially injured by the employment of chemical processes, and that it invariably becomes weak and rotten. He describes the yarns and fabrics manufactured on Claussen's plan as deficient in strength, and inferior in quality. In answer to this statement, Claussen explains the proportions of soda and acid employed, and declares it to be impossible for them to injure the most delicate fabric. Of soda, one part in 200 parts of water, and of acid, one part to 500 of water, are all that are necessary to produce the effect,—and the soda present in the straw neutralizes the whole of the acid, and forms a neutral salt—sulphate of soda.

The question of strength and quality of fibre in flax-cotton will, however, be thoroughly tested by the experiments carried on in Manchester with the existing cotton machinery. The cloth woven on Claussen's circular loom, from yarns composed of half flax and half cotton, is even and regular in texture, and various experiments are going on with higher proportions of flax and less of foreign cotton.

An instructive series of specimens was exhibited by the Chevalier Claussen, at the Great Exhibition, intended to show the universal applicability of flax fibre to the purposes of the textile manufactures. First, there were samples to illustrate the various processes resorted to in the preparation of flax for being spun alone, or mixed with various proportions of cotton, upon any of the ordinary cotton-spinning machines. There was first the flax in the straw, as pulled from the ground, cut into appropriate lengths by suitable machinery; next came flax which had undergone the saturating process in a solution of soda, required to remove the glutinous substance which binds the fibres. Then came the fibres alone, separated from the woody substance; then the flax transformed into a cotton-like substance, by the action of carbonic acid gas in the way already described. The remaining samples were the same bleached, dried, carded, and ready for spinning: also, samples of mule and throstle yarn of various numbers, some of flax only, others of various proportions of flax and cotton. These yarns were bleached and dyed of various colours, to show that flax prepared by this process is capable of receiving the same opaque dye as cotton. Samples of grey and bleached, dyed and printed cloth woven from this flax-cotton completed the series.

The second series comprised flax-wool yarns, or those in which flax and wool were mixed in varying proportions, the flax being prepared in nearly the same way as for mixture with cotton. Flannel and woollen cloths, milled and dyed of various colours, woven from this flax-wool, completed this series. The third series consisted of yarns of flax-silk, together with samples of flax, as prepared for combination with short silk on the ordinary silk machinery. A quantity of silk woven from flax-silk yarns, completed this very interesting series. The exhibitor's method of preparing flax for spinning upon ordinary flax machinery, and for its manufacture into linen fabrics, here also received illustration.

FLINT, a mineral containing about 98 per cent. of silica, and minute portions of lime, alumina, oxide of iron, and water.[1] Its specific gravity is 2.594; hardness 7.0 to 7.25: it is rather harder than quartz, which it scratches. It is usually of a grey colour, of various shades, but sometimes it is brown, black, yellow, or red. Thin fragments of the black varieties are translucent. It is fragile, and being rarely laminated, it may be broken with equal facility in almost every direction. When first taken from its native bed, it may be split with remarkable precision with the imperfectly flat conchoidal fracture observed in gun-flints: the keen edges thus produced are remarkably perfect; far more so than could be produced on the same substance in any other manner. When the water is completely dried out of the flint, it breaks with the ordinary conchoidal fracture.

Flints are found in the upper bed of the chalk formation, where they occur in regular beds, consisting either of nodules or flat tabular masses, as in the cliffs near Dover, the hills about Salisbury, and many other places. In the south of the Isle of Wight the upheaving of the chalk strata has cracked all the flints contained in them, so that, on taking out what appears to be a perfect nodule, it falls into thousands of fragments. Flint is often found in the form of sponges, alcyonia, echinites, and other fossil remains, which appear to have formed nuclei for the flint when in a state of solution. In some cases the centre of the nodule is hollow, and its sides are studded over with crystals of quartz, carbonate of iron, pyrites, calcedony, or filled with pulverulent silica, or silex mixed with sulphur. Flint also occurs in alluvial deposits in the neighbourhood of chalk. Gravel, or *ferruginous flint*, consists principally of flints rounded by attrition, the yellowish red colour being due to the peroxidisement of the iron contained in them by exposure to air and moisture.

Flint is infusible, but it whitens and becomes opaque by the action of heat. In this state it can be more easily reduced to powder, and, as such, is used largely in the manufacture of porcelain. Flint powder, glued upon wooden face wheels, is used as a polishing material. The solid flint is used as the *bouldering stone* for rubbing down to a smooth face the laps, buffs, and glaze-wheels of the cutler. [See CUTLERY.] The siliceous portion of *flint glass*, as the name implies, was formerly obtained from flints; but a purer form of silica is now found in the sand of Alum Bay and elsewhere. Flints form a good building material, their rough irregular surfaces giving firm hold to the mortar; and they resist the action of the weather perfectly. Good specimens of flint masonry may be seen in the upper chalk districts of England.

Flints were formerly in great request for the manufacture of gun-flints, and for "striking a light" with a steel. Percussion caps and lucifer matches have nearly superseded them; but, as there is still a small demand for gun-flints, it is our duty to describe the manufacture.

The nodules adapted to this manufacture should approach a globular form, the knobbed or branch flints being generally full of imperfections. Good nodules seldom weigh more than 20 lbs.: when less than 2 lbs. they are seldom worth working. They should have a greasy lustre, and should be smooth, and fine-grained. The colour should be uniform throughout the lump, and may vary from honey yellow to blackish brown. The translucency of the flint should be such that a slice of it $\frac{1}{50}$th inch thick, placed upon print, should allow the letters to be read through it. The fracture should be perfectly smooth, uniform, and slightly conchoidal.

The tools required in the manufacture are, an iron hammer, Fig. 960, with a square head not exceeding

Fig. 960.

Fig. 961.

2 lbs. in weight, with a handle about 7 or 8 inches in length. Also a hammer of well hardened steel, Fig. 961, with two points, and a handle 7 inches long: the weight of this hammer should be from 10 to 16 ounces. A roulette or disc hammer, Fig. 962, is also

(1) According to Klaproth, flint consists of

Silica	98.00
Lime	0.50
Alumina	0.25
Oxide of iron	0.25
Water	1.00
	100.00

Berzelius has found potash in the flint of the chalk of Limharmn, in Sweden. In 1,000 parts flint he detected 1.17 potash, 1.13 lime, with traces of oxide of iron and alumina, and a small quantity of carbonaceous matter, which left no residue on being ignited, and which probably produced that colour in the flint which resembles the tint of brown rock crystal. The analysis was undertaken in order to ascertain the cause of the decomposition of the surface of a flint knife; a change not unfrequently observed in flint exposed to the action of the atmosphere. The interior and undecomposed portion contained in 1,000 parts, 1.34 potash, 5.74 lime, and 1.2 oxide of iron and alumina. The decomposed portion, which could easily be rubbed off in the state of powder, contained in 1,000 parts, 3.2 potash, 3.2 lime; so that decomposition originated in the long-continued action of a liquid containing potash, which gradually replaced the lime by potash. The decomposition proceeded progressively, and had evidently commenced in the still coherent portion of the flint, and had formed a white stripe round the mass, the breadth of which varied from 0.3 to 0.4 of a line.

used: this is a small solid wheel or flat segment of a cylinder at right angles to its axis: it is $2\frac{1}{3}$ inches in diameter, and weighs 12 ounces: it is made of steel not hardened, and is fixed upon a handle 6 inches long by means of a square hole in the centre of the disc. A chisel, Fig. 963, 7 or 8 inches long, and 2 inches broad, tapering and bevelled at both extremities, is the last tool required, except a file used for restoring the edge of the chisel, which is made of steel not hardened, and is set on a block of wood which serves as a bench for the workman.

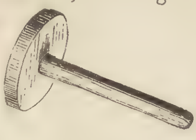


Fig. 962.


Fig. 963.

Having selected a large nodule, the workman, seated on the ground, places it on his left thigh, and breaks it up into smaller pieces of about $1\frac{1}{2}$ lb. weight, with broad surfaces and an almost even fracture: this he does with the square hammer, tapping rather than striking the nodule. Having in this way got a well-shaped flint, he next chips off with the pointed hammer the white coating of the flint, which flies off in small scales. He then proceeds to chip off scales of the length, thickness, and shape required for the formation of gun-flints. In doing this, great dexterity is required. The man balances the lump in his left hand, and strikes with the pointed hammer upon the edges of the great planes. The portions thus chipped off from the pure mass of the flint—as at A A, Fig. 964, which is a cross section of Fig. 965, the shaded

Fig. 964.


Fig. 965.

portions showing the points removed at each blow—are nearly $1\frac{1}{2}$ inch wide, $2\frac{1}{2}$ inches long, and about $\frac{1}{8}$th inch thick in the middle: they are slightly convex below, and consequently leave in the part of the flint from which they are separated a space slightly concave, bordered by two projecting ridges. These ridges, produced by the separation of the two scales, form nearly the middle of the subsequent piece, and such scales with a ridge in the middle are also fit for gun-flints. In this way the workman continues to chip or split the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the fracture required, or until the piece is reduced too much to be easily broken.

To shape the gun-flint out of these scales, the man selects such only as have the required form. He must be able to produce from every one of these scales the five different parts which constitute a gun-flint, as shown in Fig. 966; viz. A, the sloping facet or bevel which is impelled against the hammer of the lock: it should be from $\frac{2}{12}$ths to $\frac{3}{12}$ths inch thick: if thicker, it would be liable to break; if more obtuse, the scintillations would be less vivid; B, B, the sides or lateral edges, which are somewhat irregular; C, the back; D, the under surface, which should be rather convex; and F, the upper facet, which has a small square plane surface between the tapering edge and the back, for entering into the upper claw of the cock. In selecting the scales, those are taken which contain at least one of the ridges F or A. The man fixes on any tapering border of the scale to form the striking edge: he then, by means of his chisel, divides the scale into pieces of the proper width of the flint. The chisel is driven into a solid block of wood, with one of its edges upwards: that part of the flint is placed across the edge where the separation is intended to take place, and a blow from the roulette on the upper surface divides it as cleanly as if it had been cut. The back of the flint is made square by the same means. The last operation is to trim the flint, or give it a smooth and equal edge: this is done by turning the stone, and placing the edge of its tapering part on the chisel, and giving it a few blows with the round hammer.

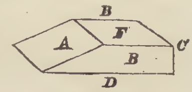


Fig. 966.

With flint of good quality a skilful workman can make 1,000 chips or scales in a day, or 500 gun-flints. In three days he can cleave and finish 1,000 gun-flints. Not more than about one-half the scales are good, and nearly half the mass in the best flints does not admit of being chipped out. One of the largest nodules seldom furnishes more than 50 gun-flints.

Such is the French method of making gun-flints. It was long kept secret; and it was not until after it had been introduced into this country that a description thereof was published by M. Dolomieu. During the war, when the demand for this article was very great, and percussion-caps had not been invented, gun-flints were manufactured at Lewisham, Maidstone, Purfleet, Greenhithe, and Northfleet. Brandon in Suffolk was, however, the chief seat of the manufacture. The flints obtained in the pits below the heath were said to be of a very superior quality, lasting longer than other flints, and being more certain in their fire. In 1837, Dr. James Mitchell visited Brandon, where he was informed that the French no longer made gun-flints, and that the Brandon makers were the only ones in the world. About 70 or 80 men were employed. The flint was obtained from a common about a mile south-east from the town. The chalk is within 6 feet of the surface. The men sink a shaft down about 6 feet; then proceed about 3 feet horizontally, and sink another shaft lower down into the chalk about the same depth of 6 feet, and sometimes they fall in with a floor of flint within this depth. They proceed again about 3 feet horizontally, and sink another shaft 6 feet; and so they proceed, going in some cases to the depth of about 30 feet. By making their shafts only about 6 feet deep, they are able to descend, and hand up the stone from one stage to another, without the aid of any machinery;

and although a windlass, rope, and bucket might save labour, they would require capital, which the poor men could not command. They pay a rent of 5*s.* to the parish for every cart-load, which is as much as three horses can draw. In the descent of about 30 feet they generally find three floors of flint, and sometimes four. At every floor they excavate horizontally for several yards, sometimes 20, below the chalk. The flint is in large blocks, which the men break into moderately-sized pieces, and hand them up from stage to stage.

Flint of the best quality, adapted to the making of gun-flints, is comparatively rare in France as well as in England. Dolomieu states that where twenty beds of flint were found lying one above another, only one or two of these would afford good flint. On the banks of the Cher flints were obtained by sinking shafts to the depth of 40 or 50 feet, from which horizontal galleries were driven through the only one good stratum met with. Dr. Mitchell was also informed that the gun-flint makers at Maidstone found only one stratum of flint fit for use in the quarries of Kent. This stratum lies under a stratum of green chalk, and is the only one which will not decompose. Fragments which have been exposed for fifty years to the air are as black as ever.

The English method of making gun-flints was very inferior to the French. Pieces were struck off the edges of a block of flint, and when it happened that they were of such a form as would answer, they were brought into shape. Such flints were unshapely in comparison of the present very elegant form of gun-flints; there was a great waste of material, and only a small number could be made in a given time. The improved method differs in some respects from the French, and, as the description contains a few interesting particulars, we will insert it here.

One man, called a *cracker*, is seated in a chair, with a thick piece of leather strapped to his left thigh, and over the leather he straps a thick piece of iron. He takes a large piece of flint-stone, and breaks it into pieces of about 2 lbs. each. He then takes one piece in his left hand, and, applying it to the plate of iron on his thigh, strikes out fragments at short distances from each other. He then strikes with his hammer on the parts of the edge of the flint which are now separated from the rest, and the effect of the blow, together with the reaction of the plate of iron on his thigh, causes a flake of about 3 or 4 inches in length to come off, there being on each side a conchoidal fracture. Of the flakes thus obtained, some are large, and others small. The man has before him three open casks, into one of which he drops the larger flakes, into the second the flakes of less size, and into the third the smallest flakes. Each cask goes to a separate workman, called a *napper*, who finishes them into flints, as *musket* flints, *carbine* flints, *horse-pistol* flints, *single barrel* flints, *double barrel* flints, and *pistol* flints. One cracker can keep three nappers employed. The napper has before him a block not unlike a butcher's block, upon which a piece of iron is nailed, from which rises a thin piece of iron, 3 inches in length and $\frac{1}{8}$th inch thick, brought to a coarse edge. The napper's hammer is a plate of steel, $\frac{1}{8}$th inch thick, fixed in a handle. He takes in his left hand a flake, lays it over the little anvil, and with his hammer breaks it into three or four flints; after which he decides which edge will be best for the flint, and from the other he chips a little off, and the whole is complete.

Dr. Mitchell says, "When we look at a gun-flint, and observe its elegant shape, and consider how admirably it is adapted for the purpose intended, we should be apt to think it had been ground into that shape with great labour and skill. Such, indeed, is the manner in which gun-flints, if we may so call them, are made in Germany from agates and conglomerates; but they are much less efficient, and more expensive."[1] During the war, the best musket-flints were sold for 42*s.* per thousand. In 1837, the price was from 7*s.* to 8*s.* Such are the particulars of a curious, and, at one time, a highly important manufacture, which may now be said to be quite extinct. Our chief object in giving all these details is to show how easily and how cheaply so difficult and refractory a material as flint may be made to assume the form and dimensions which the wants of the age dictate.

FLOOR-CLOTH, a durable covering for floors, bearing as little apparent relation to *cloth* as a finished oil-painting does to canvas. The custom of covering the floors of rooms and passages has now become almost universal, and while carpets supply the warmth and comfort necessary for the former, floor-cloths have been invented to bear the rougher usage of the latter. Floor-cloth is a cloth, or canvas, painted on both sides, the under side being plain, the upper side ornamented with a pattern. It is essential that the cloth used for this purpose be without seam; its manufacture, therefore, forms a distinct branch of trade: it is woven in very large pieces for this use alone. The pieces are from 18 to 24 feet in width, and are manufactured at looms adapted to this great width, and at which two men (one on each side) are employed in throwing the shuttle backwards and forwards. The length of the warp often exceeds 100 yards. Dundee, celebrated for its manufacture of sail-cloths, &c., is the seat of this trade.

The canvas is received at the floor-cloth manufactory in the form of bales, containing from 100 to 113 yards in length, and weighing about 5 cwt. each. One of these is opened, and from it is cut the quantity required to make a piece. This is done on the floor of the *drying-room*, whence the piece thus cut off is carried (wound on a wooden roller) to the *frame-room*. In this room a number of substantial wooden frames are set up, a few feet apart, and on these the canvas is to be stretched, preparatory to the painting. A space of a few feet occurs between every two frames, and this is occupied by a scaffolding of four tiers, any one of which may be reached by means of a ladder placed at one end of each frame. The roller containing the canvas is set up on end, and rests on a low carriage, which is wheeled along as the canvas is unwound. But the first step

(1) Jameson's Edinburgh New Philosophical Journal, vol. xxii.

is, to bring it parallel with one of the upright ends of the frame, and make fast its edge by nailing it from top to bottom to the upright post. The unwinding of the canvas then proceeds, a temporary fastening being made to the top beam by means of a *quickset*, or arrangement of hooks, preparatory to the subsequent equable straining of the immense surface.

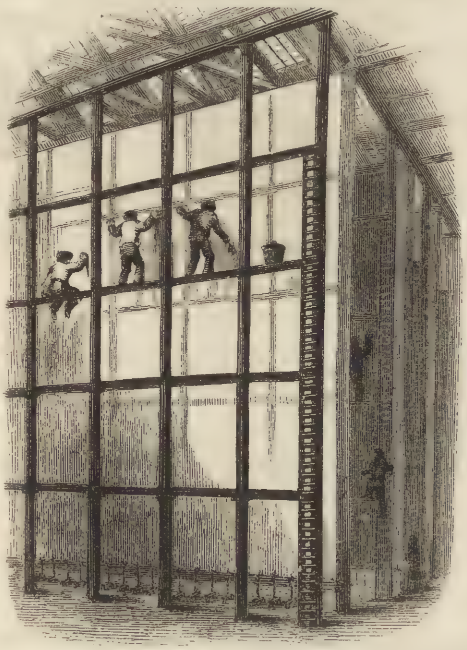


Fig. 967. THE FRAME-ROOM.

When all the canvas is unrolled, the other end is also attached to the frame; but the whole yet remains hanging loosely, and has to be tightened by lengthening the frame by means of screws. The upper and lower horizontal edges have also to be secured to the beams, and stretched out in a similar manner. The whole at length becomes nearly as tight as the head of a drum, and if this be done in dry weather, and a change to wet suddenly take place, the tension is sometimes so much increased as to split the canvas; this arises from the natural property of the spiral fibres of flax to become shorter from moisture, and consequently, to make the canvas shrink.

In order to prepare this extensive surface for the reception of the paint, a weak solution of size is laid on with a brush, and while it is yet damp the canvas is well rubbed with pumice-stone. This softens down any irregularities, while the size fills up the interstices, and keeps the paint, which is afterwards applied, from penetrating too far, the effect of which would be to make the floor-cloth hard and brittle. This *size priming* and *pumice scouring* is carried on from the top of the frame downwards, one man applying the size, while two follow with the pumice-stones. The back surface of the cloth is primed first.

This first process being completed, and the surface dry, a coat of paint is applied, stiffer than that used in house painting, and containing little or no turpentine. It is first thrown on in dabs, with a short thick brush, shown in the man's left hand in Fig. 968, and afterwards spread with a steel trowel, Fig. 969, about 2 feet long, very elastic, and having the handle near one end. When a large surface has been gone over with considerable force, the trowel is held obliquely, so that its edge alone may act, and thus a large portion of the paint is scraped off again, and the high threads of the cloth become visible. But the paint has been thoroughly worked into the web of the cloth, filling up inequalities, and making the surface level. The *trowel colour*, as it is called, is left to dry during from 10 to 14 days, according to the weather; a second and thinner coat is then smoothly laid on with the trowel, and when this is also dry, certain marks are made which shall enable the manufacturer at any time to identify the cloth as of his own make. This completes the operations for the under side of the canvas. But between the two coats of paint thus applied to the under side, the process is commenced on the upper side or face, by applying size and pumice-stone, as before. A trowel colour is also laid on, but when this is dry, the face is carefully pumiced, in order to get rid of the slightest lump or knot. Two more trowel colours are added with the use of the pumice-stone between each. A fourth coat laid on thinly with a brush, and called *brush colour*, forms the ground of the future pattern, and completes the floor-cloth, with the exception of the printing.

Fig. 968.

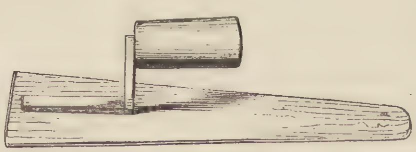


Fig. 969.

The series of operations thus briefly alluded to, occupies from two to three months, during which time, if the article be of the best quality, the canvas has increased in weight nearly fourfold; but if an inferior sort of floor-cloth be intended, then the number of coats and the weight will be proportionally less. The cloth is now to be removed from the frame on which all these operations have been carried on: this is done by running a sharp knife along the edges so as to detach it; it is then covered on the face with paper, rolled and hauled up into the printing room above by means of ropes and pulleys. The printing is performed on a flat long table, and the floor-cloth is drawn up and along its surface in portions as required. Wooden blocks, similar in principle to those used in wood engraving, are employed to stamp the pattern, but as the latter generally consists of several colours, a separate block

is required for each colour. There are, therefore, as many separate printings as colours, and these are sometimes seven or eight in number.

In preparing a set of blocks for printing floor-cloths, an accurate coloured sketch of the design is first made on stout paper. A blank sheet of paper is then placed under this, and by means of a sharp point, all that portion of the device including one colour is marked upon the under sheet in a series of dots, or holes. This sheet being removed, another is placed under the pattern, and all the figures of another colour are pricked out in a similar manner. Thus, the pattern is dissected on as many sheets of paper as there are colours to be printed. This being completed, the several parts have to be transferred to the blocks. For this purpose one of the pricked sheets is fixed on the surface of a block, and a little powdered charcoal is dusted over it from a muslin bag, and dabbed upon the paper so as for it to penetrate the holes. A dotted line is thus made upon the block, which serves to guide the pencil of the engraver when the paper is removed, and enables him to draw the portion of the pattern required for that block. The same plan is pursued with other blocks, which are then ready for the engraver, who cuts away the wood and leaves the pattern in relief. When a solid mass of black or white occurs in the pattern, (as the squares employed to imitate marble,) it is sometimes filled in by hand, or the wood is cut into a series of narrow channels, crossing each other at right angles. These hold the ink, and produce the intended effect, whereas a large unbroken surface fails to take up the colour equally. Sometimes, brass wire is inserted to form a pattern, and then ground down level; but this makes the block inconveniently heavy.

The engraved portion of the block is of pear-tree wood; to prevent warping, this is fastened to two blocks of deal, glued and pressed together so as for the fibres of each to cross the other at right angles. The printing surface is about 18 inches square, and is soaked in oil while new, that it may take up the colour more readily. The cost of a block, including the engraving, varies from 2 to 4 guineas, so that in large establishments, where several thousand blocks are required, the value of this portion of the stock is great. The blocks not in use are carefully preserved in a room set apart for that purpose, and where a tolerably equal temperature is maintained throughout the year.

The printing of floor-cloth is thus conducted. On a table is placed a number of flat cushions, each about 3 feet square, consisting of a pad of flannel covered with smooth floor-cloth. By the side of each cushion stands a pot of colour, from which a boy called a *tearer*, or *tierer*, takes up a portion with a brush, and spreads it over the cushion, first passing his brush from top to bottom, and then across the cushion, till a shallow but equable bed of paint is prepared. Each cushion receives one colour only, and when the printing is in several colours, the boy has his full employ in keeping the cushions well supplied. A portion of floor-cloth being unwound and spread upon the printing table, a man hastily passes a steel scraper over it slightly to roughen the surface for receiving the colour, and a

Fig. 970. PRINTING FLOOR-CLOTH.

second follows with a hard scrubbing-brush for the same purpose. The printers follow next, their number

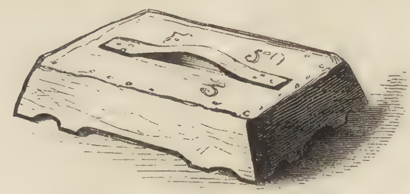


Fig. 971.

agreeing with the number of colours to be printed. The first, holding his block by a handle attached to the back, as shown in Fig. 971, presses it down on the cushion to imbibe the desired colour, then takes it to the cloth, and carefully placing it at the right hand corner, holds it firmly, at the same time striking it several times with the handle of a heavy hammer, Fig. 972. He then lifts up the block, and a clear impression is left of a portion of the pattern in one colour only. Taking a fresh charge of the same colour, he makes a second impression by the side of the first, and so on in regular rows along the whole extent of the cloth upon

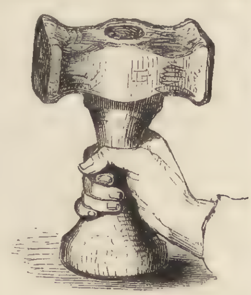


Fig. 972.

the table, taking care to keep his squares perfectly true and even. When this first printer has advanced a little way, a second charges his block with a different colour, and begins precisely where his comrade did, delivering his portion of the pattern with a few strokes of the hammer, as before. After him follows a third, and as many more as may be required to form the most elaborate pattern. Thus the device is rapidly perfected, and the first printer, who is necessarily in advance of his comrades, has time to examine the work and to supply any flaws with paint of the proper colour, laid on with a camel's hair pencil.

Suppose the pattern be in four colours, viz. black, white, and light green, on a dark green ground, as shown in the finished pattern, Fig. 973. The ground having been previously prepared, the printing is performed by three blocks in succession, one of which, Fig. 974, takes up and prints the white colour; Fig. 975 takes up and prints black, and Fig. 976 takes up and prints the light green colour. As the printing proceeds, the cloth is turned over and gradually descends through an opening in the floor to the drying-room, where it sometimes remains for months. The process can be hastened by the use of drying oils, but this makes the floor-cloth brittle. Narrow widths of floor-cloth for passages, stairs, &c. are first cut the required width, and then printed in the same manner as the wide, except that a space is left on each side for the border, which is put on with smaller blocks afterwards.[1]

Fig. 973. THE FINISHED PATTERN.

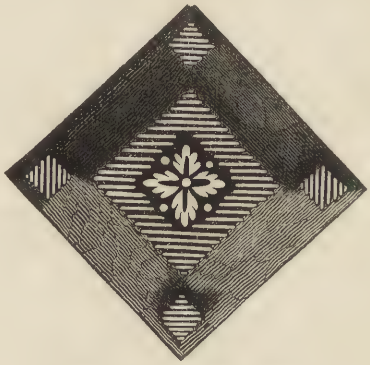


Fig. 974. THE WHITE PORTION

Fig. 975. THE BLACK PORTION.

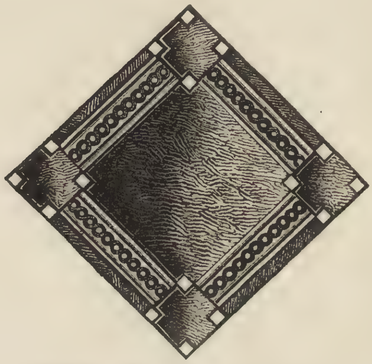


Fig. 976. THE LIGHT GREEN PORTION.

FLOORS and PARTITIONS. The term *floor* is derived from the Anglo-Saxon *flor*, (German *flur*,) and originally signified a field, or flat-spread surface.

The construction of floors presents less scope for ingenuity, and therefore possesses less interest, than the higher branches of framing and trussing, but is nevertheless well worthy of attention. The carpenter's art extends only to the provisions for strength and durability, as he does not enter on the subject of Inlaid work, Parquetage, or other modes of ornament. [See INLAYING.]

Floors are commonly distinguished as, 1. *Single joisted;* 2. *Double*, and 3. *Framed.* In modern practice these three kinds may be regarded as generally applicable to areas of progressively increasing dimensions. In old work, floors of small surface were often made either double or framed, but as a general rule, modern artificers are only led by necessity to pass from a simple to a more complex form. Some curious specimens exist which can be classed under neither of these heads, but such are rather interesting for their ingenuity than valuable as examples for imitation.

(1.) *Single joisted floors* are the most simple. Fig. 977 shows a section of this flooring, made parallel with the boarding. They have the planking or actual

Fig. 977

floor supported only by a single series of parallel timbers called *joists, a a*, or, collectively, the *naked flooring.* These rest upon *wall plates* built into the walls of the edifice, and are cogged down upon these plates in the manner shown in Fig. 988. The laths for supporting the ceiling are nailed to the under side of these joists.

As the strength and stiffness of a beam to resist transverse strain, increases much more with any given addition to its depth, than with an equal addition to its breadth, these joists are made very deep in pro-

(1) We are indebted to Messrs. Smith & Baber, of Knightsbridge, for the illustrative sketches, and for most of the information contained in this article.

portion to their breadth or thickness. But this latter dimension should in no case be less than 2 inches, or the piece will be liable to injury from the nailing. In good substantial work, 12 inches apart from centre to centre is a proper distance for the joists, but this is often exceeded in slight and cheap erections.

In all these constructions it is not sufficient to make the work so strong that it shall not *break*, but it must be made so strong that it shall not *bend* in any perceptible degree under the strain it has to bear. Therefore, in deciding on the dimensions of the timbers to be used in floorings, regard must be had to their sufficient stiffness, and not merely to their sufficient strength. Now the stiffness of a beam in supporting a transverse strain varies as $\frac{bd^3}{l^2}$ (C), where b is the breadth, d the depth, and l the length; and C is a constant quantity dependent on the kind of material employed, and determinable by actual experiment.

Hence, to find the proper depth for a common joist, when its length and breadth are given, we have $d = \sqrt[3]{\frac{l^2}{b}}$ (C), where b and d are measured in inches and l in feet. The value of (C) is then, for fir, 2·2; and for oak, 2·3. It is obvious that this equation may be used to determine any one of the measures b, d, or l when the other two are given.

When the length of the joists exceeds 8 feet, they must be *strutted* to prevent their tendency to turn over sideways. This is done by nailing cross-pieces of wood between them, as shown on the right-hand of Fig. 980, or by simply driving short ends of plank between them. And in case the length of bearing exceeds 12 feet, there should be a row of struts at each four feet of the length of the joists.

Sometimes the joists cannot be carried through to the wall at one end, as, for example, when they come

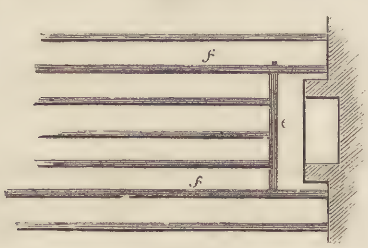


Fig. 978.

opposite to a fire-place, or to a staircase, then the short end is supported on a *trimmer*, *e*, Fig. 978, which is tenoned into the two adjacent through-joists. The joint for the ends of the trimmer is the *tusk tenon*. The long part of the tenon is usually carried quite through the joists, and pinned, or preferably wedged on the outside. (Fig. 978.) The two *trimming joists*, *f f*, into which this cross-piece is tenoned, are made a little

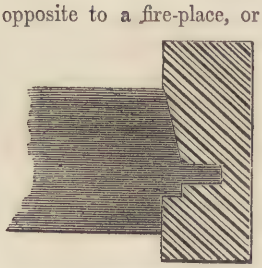


Fig. 979.

thicker than the other joists in the proportion of $\frac{1}{8}$ inch additional thickness for each joist the trimmer has to sustain. The dimensions of the trimmers may be calculated by regarding them as binding joists.

It should be observed that when the length of the joists exceeds 10 or 12 feet, it is very difficult to prevent cracks in the ceiling beneath. Hence, when a perfect ceiling is indispensable, a double or framed floor should be used for all areas exceeding 10 feet in their least dimension. In ordinary domestic buildings these cracks are less regarded, and therefore the use of the single-joisted floor is not so limited.

An improvement on the common arrangement (shown in section in Fig. 980,) is made by cutting

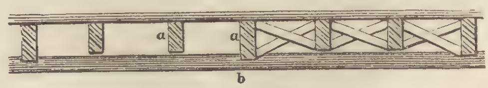


Fig. 980.

each third or fourth joist rather deeper than the others, and using *ceiling joists*, *b*, which are notched upon these deep pieces, and nailed up to them. The ceiling laths are then nailed on these lower joists. Such a floor is but little deeper than one of the common form; it is much less pervious to sound, and the ceiling is less liable to be cracked. The rule for the strength of ceiling joists is given lower down.

(2.) The *Double floor* is applicable in cases when long timber cannot be obtained in sufficient quantity for single joisting, or when it is desirable to divide

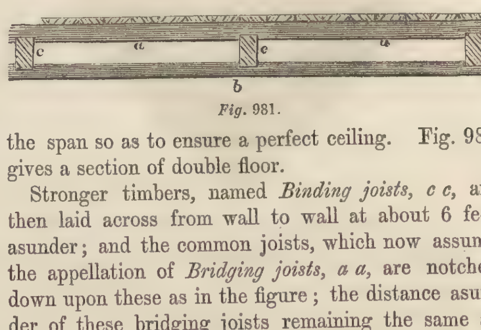


Fig. 981.

the span so as to ensure a perfect ceiling. Fig. 981 gives a section of double floor.

Stronger timbers, named *Binding joists*, *c c*, are then laid across from wall to wall at about 6 feet asunder; and the common joists, which now assume the appellation of *Bridging joists*, *a a*, are notched down upon these as in the figure; the distance asunder of these bridging joists remaining the same as before. The ceiling joists b are nailed up to the under-surface of the binders, or are mortised into their sides.

The formula for finding the dimensions of binding joists is, as before, $d = \sqrt[3]{\frac{l^2}{b}}$ (C), here (C) being 3·42 for fir, and 3·53 for oak. This is supposing that the binders are not more than from 4 to 6 feet apart.

In all these cases, the ceiling joists, to which the laths for supporting the plaster are nailed, need be no thicker than is sufficient for giving them a good hold on the nails. The equation $d = \sqrt[3]{\frac{l}{b}} \times 0{\cdot}64$ will give the relative dimensions for fir. For oak, the constant 0·67 must be taken. Their breadth rarely exceeds $1\frac{1}{2}$ to 2 inches.

(3.) The third, or *Framed floor*, is applicable when

very large surfaces are to be floored with great accuracy. Strong balks of timber, termed *girders*, *d d*, Fig. 982, are laid across at distances of from 8 to 10 feet asunder, and the binding joists *c* are tenoned into these main pieces. On the binders the bridging joists *a*, ceiling joists *b b*, and flooring are supported as before described. The spaces divided off by the girders are named *Bays*. If included between two girders, it is a *Case-bay;* when between a girder and the wall, it is a *Tail-bay*. Thus, also, the work included in each of these spaces is called a *Bay of joisting*.

Fig. 982.

The same equation is used to determine the dimensions of girders, as of binding or bridging joists, but the value of *c* is now increased to 4·2 for fir, and 4·34 for oak. The girders are let into the walls for a depth of 10 or 12 inches, and rest on strong pieces of timber, named *templates*, which serve to distribute the pressure. In order also to prevent as far as possible the decay of the ends of the girder, these should not be built close into the wall, but about an inch of air-space should be left all round them. Fig. 982 gives a section of a framed floor made parallel to the plane of the binding joists, and therefore across the girders.

It is a common practice to saw the balks of timber intended for girders down the middle, and to bolt the two halves together, back to back, keeping them an inch or two apart by small pieces of wood placed vertically between them. This method is shown in the figure. Several advantages arise from this practice: it enables the heart of the timber to be examined as to its perfect soundness; it allows greater freedom for the passage of air around and between the pieces, and it gives the workman the opportunity of equalizing the strength of the two ends of his girder by turning one half end for end with the other.

Girders for long bearings should always be made as deep as possible; but where it is not practicable to sacrifice sufficient depth in the floor for this purpose, the girders must be made considerably wider, and should be placed nearer together.

When the span of the floor is greater than can be covered with any piece of timber attainable, recourse must be had to iron, or else the girders must be *trussed*. Cast-iron girders are now readily obtained in almost all places. They are made of the section shown in Fig. 983, and as this metal yields much more easily to extension than to compression, the lower flange (the part extended by a weight placed above) should have six times the sectional area of the upper or compressed flange. In computing the strength of such a casting, it is usual only to reckon on the strength of this lower flange, assuming, from the nature of the material, that if this be made strong enough to resist the extending force, the top will certainly have sufficient substance to support the compression. Hence the following rule for the strength of cast-iron beams:—Multiply the area of the lower flange in square inches by the depth of the beam in inches, and divide by the length in feet. This product multiplied by 2.166, gives the breaking weight at the centre (or half the breaking weight if distributed equally over the whole length), in tons. From one-third to two-fifths of this weight is the limit of safety in practice. The binding joists in such girders rest on the lower flange, being confined between small bracket-shaped pieces cast in the angle between the vertical rib and lower flange.

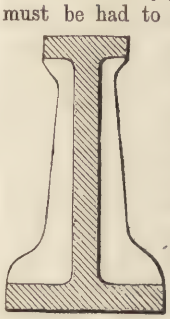


Fig. 983.

The immense strength obtainable by the use of wrought-iron in thin plates, shows that this material might be advantageously used in many cases to span considerable widths.[1]

But in case metal girders are not applicable, a built-up wooden girder may be used. This may be made by connecting a balk of some hard rigid wood with a straight-grained tough timber, using the former, of course, for the upper or compressed part, and the latter for the lower or extended part. They are prevented from sliding on one another, either by

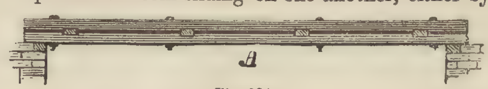


Fig. 984.

keys, as in A, Fig. 984, or by being tabled together, as in B, Fig. 985. In this last case a *king-bolt* is advan-

Fig. 985.

tageously added to tighten the joints, as in the figure. Bolts may be used to bring the pieces together, or preferably the upper piece may be tapered from the middle to each end, and the two drawn together by hoops driven on. Another mode of building up a beam, is that of cambering or curving it, and holding it in this position by bolts or straps. Fig. 986

Fig. 986.

shows the half-length of a cambered beam thus applied at the upper part of a built-up girder. If it is necessary to use more than a single length of timber, the upper beam may have a plain butt-joint at any convenient part of the span, but the lower beam, if jointing be unavoidable, should have its scarf near to one end of the span, and by no means at or near the middle, where the greatest strain is exerted. For

(1) The account of the Britannia and Conway Tubular Bridges by Edwin Clark, Esq., C.E., gives a mass of most valuable information as to the ascertained strengths of most forms of metal and wooden beams and girders.

the scarf the joint shown at Fig. 492, Art. CARPENTRY, may be used.

A beam is sometimes trussed with iron, as in Fig. 987, but this method is not recommended in practice.

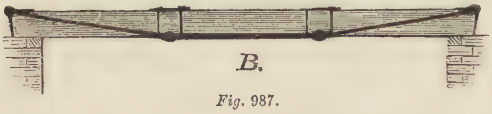


Fig. 987.

It requires great accuracy of fitting, and is liable to have all its efficiency destroyed by small changes of dimension in its parts.

The cost of flooring is estimated by the *square* of 100 square feet.

The following general principles apply to all kinds of flooring. The bearing timbers which sustain the weight, should, if possible, be laid across the narrowest way of the room. In a single-joisted floor, the joists should run in this direction, but in a double floor, the binding joists are the bearing pieces, and should be laid this way. In a framed floor, the girders become the bearing pieces, and should then have this advantage given them. In a square room, of course, the directions are immaterial.

With any given quantity of timber, the single-joisted floor has been proved, by direct experiment, to be the strongest form of any, and it also possesses the advantages of requiring fewer joints, and of distributing the weight borne more directly and generally over the walls. Against these merits, are to be laid the difficulty, when the span is great, of procuring a sufficiency of long timber, as well as the liability to disfigurements from partial strains of heavy goods or furniture, and finally, the facility with which sounds are transmitted unless some special means of prevention be adopted.

Flooring-timbers should never be laid obliquely, but should be placed parallel to one or other wall of the room. Girders should never be laid over spaces, such as doors or windows. If, however, this position be unavoidable, the templates should be strong and long enough to throw the weight well on the piers.

When first laid, the floor ought to be rather high in the centre, to allow for settling at the joints. When all is settled, the floor should be perfectly level. If it is cambered up, it must evidently exert a thrust outward on the walls. If so weak as to sink down in the centre, it as evidently tends to pull the wall-plates inward. In either case, the ceiling beneath will be cracked and disfigured. It is only when perfectly level that the floor exerts no thrust or strain on the walls.

Common cheap floors are often laid with boards of from 7 to 9 inches in width, but the best floors have their boards or battens not more than from 3 to 5 inches wide. These last do not, of course, show the shrinkage of the stuff, as the ordinary constructions do in too many cases.

In all the equations for dimensions, the constant for oak is higher than that for fir, on account of the liability of this timber to be cross-grained, and thus to become weakened in cutting.

Of extraordinary floors the one most worth mentioning appears to be that applied in Amsterdam to a room 60 feet square. This had neither joists nor girders, but consisted merely of three thicknesses of $1\frac{1}{2}$-inch boards laid one on the other and securely nailed together, and to very strong wall-plates. The lowest layer ran diagonally from corner to corner, the second layer also went diagonally, but from the opposite corners, so as to cross the first thickness at right angles. The upper set ran in the usual way from side to side. The floor thus became a strong thin plate of wood, supported and strained all round its edges.

Short joists may also be used by being tenoned one into the other, and made to rest at the other end on the wall-plates, as shown in Fig. 988.

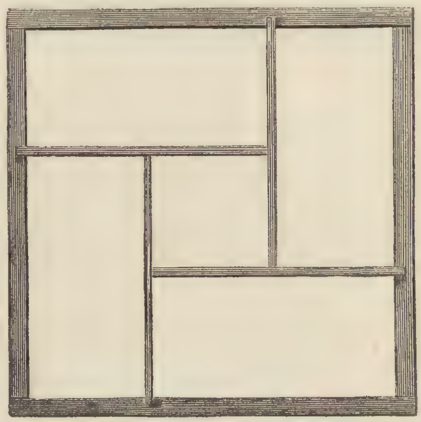


Fig. 988.

Partitions may be advantageously considered in this place. Their construction comes under the charge of the carpenter, and is usually proceeded with at the same time as that of the floors. Indeed, the constructions of the two are in some respects connected.

The term partition is restricted to those internal divisions of a building, into the essential constructive part of which, timber enters in a greater or less degree. These divisions either consist of a framework of wood simply covered with laths and plastered, or the spaces in the wooden frames are filled in with brickwork. In the first case it is said to be a *quarter partition*, in the last case it is called a *brick-nogging partition.*

Partitions are sometimes constructed so as to be dependent on or connected with the floor above or below, and in other cases they are made wholly independent of these floors, and self-supporting. One of the first kind need consist only of upright pieces of timber of a width sufficient to bear nailing, (say from $1\frac{1}{2}$ to 2 inches,) and of a depth suitable to the intended thickness of the partition, tenoned into a horizontal sill at top and bottom, and stiffened by struts placed between them. The distance between these uprights may be from nine inches to a foot. The laths are nailed upon these pieces, and covered with plaster. Such a partition as this, if it be not supported continuously up from the bottom of the

building, should rather be strapped from the floor or truss above it, than allowed to bear on the floor beneath. The weight is then not unduly thrown on the joists beneath, with the certainty of cracking the ceiling, nor does the partition become liable, by its settlement, to tear away from the ceiling of its own room, and thus produce unsightly cracks in the plaster and cornice. But though it is often practicable to obtain a continuous support up from below, it is by no means desirable to use it, as any unequal settlement of the main walls, and of the internal division, must crack the partition. Therefore it is better in all cases to make the partition self-supporting, and dependent only on the two main walls. The partition becomes in fact a very deep truss.

If there is no doorway to be made through from one room to the other, the ordinary king-post truss may be used for short spans. When the span is considerable, or when doorways are to be made through the partition, the truss may assume the queen-post form, as in Fig. 989. In Fig. 990 is shown a form of

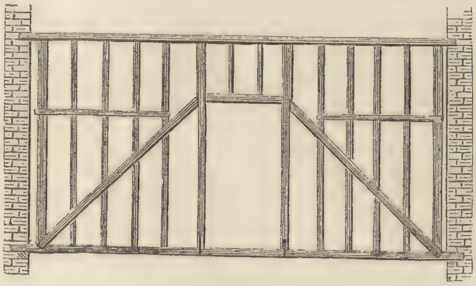


Fig. 989.

partition adapted for two doorways. The sill or tie must be either carried under the flooring, as in Fig. 989, or may be carried over the head of the doorway, as in Fig. 990.

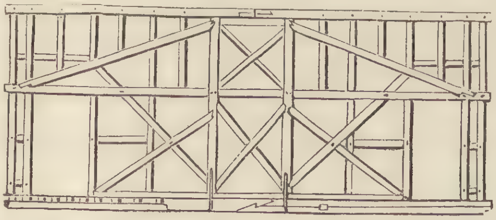


Fig. 990.

The principals of the truss (which in partition-work are called *braces*) should be inclined at an angle of about 40° to the horizon. This will, therefore, to a great extent, determine the form of truss to be employed. The nature of the strains on the several pieces may be determined by the rules already given in the Article CARPENTRY. In deciding on the substance of the timbers, due regard must, of course, be had to the weight to be borne by the truss, as in some cases the partition has not only to support itself, but also a floor, and perhaps other partitions above.

Any small shrinkage of timber or slipping at joints, will do more harm in partition-work than the same amount of yielding in almost any other part of a building, as such failures are sure to be attended by cracked walls and ceilings. Partitions should therefore be built of well-seasoned timber, the joints carefully drawn and fitted, and the whole allowed to stand in its permanent place some time before it is lathed and plastered. Settlements can then be remedied if serious, or if not, the timbers having once taken their bearings, may be safely covered.

In a brick-nogging partition, the wood pieces (called *nogging-pieces*) should project a little on both sides beyond the brickwork, to allow of the laths being nailed to them. When the thinness of a partition is not so much an object as its strength and impenetrability to sound, it is better to nail the uprights which take the laths on the outsides of the main truss, instead of cutting them so as to fit in between the timbers of this truss. This plan takes rather more timber, and makes the partition thicker, but it renders it much stronger, and also far less pervious to sound.

Partitions are measured like floors, by the *square*.

In computing the required strength of the pieces in a partition, the following may be taken as the weights of the parts to be supported:—

A square of common quarter partition .	1,500 to 2,000 lbs.
A square of single-joisted flooring . . .	1,300 to 2,000 ,,
A square of framed flooring with counter flooring	2,500 to 4,000 ,,

It is a safe plan to use the highest numbers when the truss is of considerable length, and to employ the lower numbers when the span over which the truss is to be carried is short.

FLOSS-SILK, a name applied to the portions of ravelled silk broken off in the filature of the cocoons of the silk-worm. It is carded like cotton or wool, and spun into a soft coarse yarn or thread, with which common silk fabrics are made. See SILK.

FLOUR. See BREAD.

FLOWERS of sulphur, a term applied to sublimed SULPHUR. The old chemists used also to speak of *flowers of benzoin, flowers of zinc*, &c., from the resemblance of these sublimed substances to the dust or pollen of flowers.

FLOWERS, ARTIFICIAL. The manufacture of artificial flowers, first brought to a high degree of excellence by the Italians, and now most successfully prosecuted by the French and English, is one of no small importance considering the amount of skill and labour which it brings into requisition. The perfection to which this art has been carried was illustrated in a remarkable manner in the Great Exhibition. The imitations of vegetable nature, there shown in its blooming freshness and in its decay, were perfectly wonderful, embracing the most difficult and complicated forms, as well as the most simple. The grotesquely varied shapes and delicate colourings of Orchids and other tropical plants, were as successfully imitated as the familiar forms of rose, lily, and mignonette. So accurate, indeed, were the copies of rare and fragile plants, that we have the testimony of a professor of botany to their value in reference to his science.

Such being the successful results of this manufacture, it must no longer be considered as a mere auxiliary to the toilet. It is worthy of a higher rank than has yet been accorded to it; and the ingenious processes connected with it are well deserving of notice. The first attempt at making artificial flowers among civilized nations, was by twisting ribbons of different colours somewhat into the shape of flowers, and fastening them to wire stems. This yielded to the use of feathers, which were far more elegant, but could not always be made to imitate in colour the flowers which they represented, there being considerable difficulty in getting them to take the dyes. Where the plumage of birds is of great brilliancy, the natural colours admirably answer the purpose, and do not fade or lose their resplendent hues. Thus in South America, the savages have long known how to fabricate beautiful artificial flowers from such plumage. In Italy the cocoons of silkworms are often used, and have a soft and velvety appearance, while they take a brilliant dye. In France the finest cambric is the chief material, while wax is also largely employed. The arrangement of the workshop, and the variety and use of tools, where flower-making is practised on a large scale, are as follows:—

A large and well-lighted room, which has the means of warmth in winter, is selected, and along its whole extent is placed a table, similar to the writing tables used in schools, where the work-people may have a good light as long as possible. This table is fitted with drawers containing numerous compartments, arranged so as to receive and keep separate the small parts of flowers, such as petals, stalks, minute blossoms, catkins, buds, leaves not mounted on their stalks, and all other parts not fit to be placed among more finished specimens. It is desirable that the table be covered with oil-cloth, so that it may be frequently cleansed, by washing, from the stains of the different colours employed. Along the whole extent of this table are placed flower-holders, that is, light frames with horizontal iron wires, to which the flowers, when attached to their stalks, are suspended by merely crooking the end of the stalk, and hanging it on the wire. Sometimes tightly strained packthread is used instead of wire. Figs. 991 and 992 represent

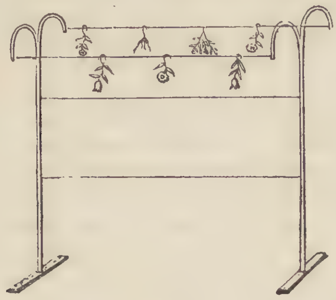


Fig. 991.

two forms of flower-holder; in both cases the frame is fixed to the table. Along the table are also ranged bobbin-holders in considerable numbers, not unlike those used by weavers. The bobbin-holder is a rod of iron, Fig. 993, about six inches high, fixed in a massive leaden or wooden base. On this rod is threaded a large bobbin, on which is wound a quantity of silk or wool. On its summit may be fixed a nut to prevent the bobbin when in rapid motion from whirling

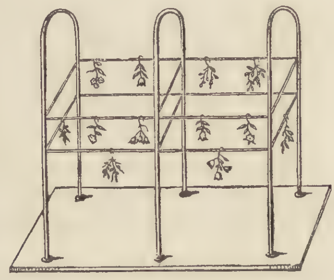


Fig. 992.

Fig. 993.

off the rod, but this is often omitted. Ladies who work for their pleasure, frequently have this bobbin-holder made in an ornamental form, the base being covered with bas-reliefs, and the nut at the top taking the form of an arrow, a blossom, &c. But the more simple and free from ornament, the better is the holder for use, any unnecessary projections only acting as so many means of entangling the silk.

The flower-maker does not take up flowers or their parts with the fingers, but with pincers of the simplest description, Fig. 994, which are incessantly in use.

Fig. 994.

With these the smallest parts of the flower can be seized, and disposed in their proper places, raised, depressed, turned about and adjusted according to the taste of the artist, and her appreciation of natural forms. It is with the pincers also that any little contortions of the extremities of petals, and irregularities in their form and in the arrangement of stamens, are copied. The proper length of this tool is about five inches. Each workwoman brings one for her own use, and keeps it close at hand. Dressing-frames of various sizes form another part of the furniture of the work-room. On these are stretched the materials

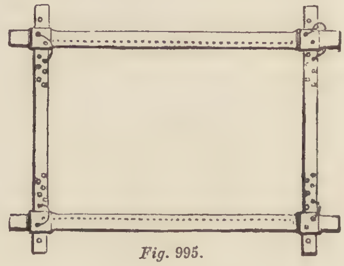


Fig. 995.

which are gummed and dyed. A dressing-frame, Fig. 995, consists of two uprights of hard wood, with two cross pieces of the same, capable of adjustment. The frame is fitted with crooks for the attachment of the material, or with a band of coarse canvas to which the material can be sewn. These frames have

no feet, and are fitted sometimes against a wall, sometimes upon a chair. When covered with the material, they are hung up against the wall by one of the cross pieces, until it is time to dismount them.

There are also various useful implements, called by the work-people "irons," for cutting out petals, calyxes, and bracts, and for giving to leaves those various serrated and other forms, which produce such wonderful variety in foliage. These cutting tools, two of which are shown in Figs. 996 and 997, are of iron, with a hollow handle, flat at its upper extremity, that the hammer may be readily applied. They are about four or five inches long, and of numerous sizes and varieties. That they may cut rapidly and clearly, the edges are occasionally rubbed with dry soap. When a leaf becomes attached to the interior, and cannot be shaken out, a little ring of wire, Fig. 998, is introduced in a hole, *j*, Fig. 997, left for that purpose to disengage it. The material is doubled several times under the cutter, so that several petals or leaves may be cut out at once. The block on which the leaves are cut out is rather a complicated affair. It is placed near a window, and as far as possible from the workers, that the blows of the hammer may not interfere with their employment. Sometimes it consists of a very stout framework of timber, on which is placed a mattress of straw to deaden the blows, and upon this mattress a thick smooth piece of lead, forming a square table, Fig. 999. In some cases a solid block of timber is used, a portion of the trunk of a tree taken near the root, and on this the mattress and the leaden table are placed. The hammers used at this work are short and heavy; one is especially adapted for smoothing the surface of the lead when it becomes indented all over by the blows of the workman.


Fig. 996.

Fig. 997.


Fig. 998.

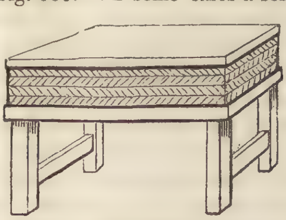


Fig. 999.

The cutting out of the leaves and petals is only a preliminary operation to the more perfect imitation of nature: the leaves must next be gauffered to represent the veins, the folds, and the endless touches and indentations which are found in the natural plant. Gauffering is executed in two ways, the first and simplest being that which merely gives the hollow form to the petals of roses, cherry-blossoms, peach, hawthorn, and numerous other flowers which preserve, until the period of decay, somewhat of the form of a bud, all the petals beautifully curving inwards. To imitate these, the gauffering tools are simple polished balls of iron fixed on iron rods, with a wooden handle attached, as shown in Fig. 1000. The balls are of various sizes, from a pin's head upwards, to adapt them to the minute blossoms of such flowers as the forget-me-not, which require only the slightest degree of curvature, and to the large flowers of camellia, dahlia, mallow, &c., where the curvature is often very great. These balls are made slightly warm, so as to fix the forms decidedly, without effacing the colours. The petals are placed on a cushion, and the iron is pressed against them. But curvature alone is not sufficient: there is, in many petals, a decided fold or plait up the centre, springing from the point where it is attached to the germen. This fold can be obtained by the use of a prism-shaped iron, Fig. 1001. Conical, cylindrical, and hooked irons, Figs. 1002, 1003, are also useful to imitate the various minutiæ of the blossoms. A cushion near each artist serves as a rest to the gauffering irons, which must be preserved from the least taint of dust, seeing that they are applied to the most delicately-beautiful portions of the flower. The veins and curves of leaves are given by gauffers composed of two distinct parts, on each of which is severally moulded in copper, the upper and under surface of the leaf, as shown in Fig. 1004. Sometimes, one part is of iron, the other of copper. It is necessary to have a very large assortment of these gauffers; in fact, they should correspond in number with the cutting-irons by which the forms of leaves are punched out. The leaf or leaves being inserted in the gauffer, a powerful pressure is given to stamp the desired form. This is accomplished either by means of a heavy iron pressed on the lid, or by two or three smart blows of a hammer, or, better still, by the uniform action of a press, such as is shown in Fig. 1005. Besides the above articles, the workshop is provided with an abundance of boxes, scissors large and small, for cutting wire, as well as textile fabrics, camels' hair pencils, sponges, canvas-bags, &c., that everything likely to be needed by the work-people may be immediately at hand.


Fig. 1000.


Fig. 1001.


Fig. 1002.


Fig. 1003.

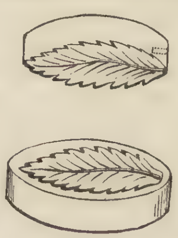


Fig. 1004.

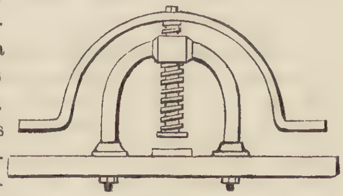


Fig. 1005.

The material of which flowers are made is, first and best, (as already stated,) French cambric, but a great quantity of Scotch cambric, jaconet, and even fine calico, are also used. For some descriptions of

flowers, clear muslin, crape, and gauze, are wanted; and for some very thick petals, satin and velvet are necessary. These materials are provided in various colours, as well as in white, but fresh tints have frequently to be given. These are laid on with a sponge, or a camels'-hair pencil, or the petal is dipped in colour: a quantity of green taffeta should always be at hand for leaves. The colouring matters used in dyeing the material for the petals are as follows. For red, in its various shades, *Brazil wood* is largely used, also carmine, lake, and carthamus. The best way of treating Brazil wood is to macerate it cold in alcohol for several days; a little salt of tartar, potash, or soap, will make this colour pass into purple; a little alum gives it a fine crimson-red, and an acid will make it pass into yellow, of which the shade is deeper according to the quantity employed. Carmine is better in lumps than in powder; diffused in pure water, it gives rose-colour; a little salt of tartar brightens the tint. Carthamus is dissolved cold in alcohol; heat, as well as the alkalies, causes it to pass to orange. The acids render it of a lively and pure red; a very delicate flesh-colour is obtained by rinsing the material coloured with carthamus, in slightly-soapy water. Blue colours are prepared by means of indigo, or Prussian-blue. Sometimes balls of common blue are used, steeped in water. Indigo is first dissolved in sulphuric acid. This is then diluted with water, and powdered chalk or whitening is added until effervescence ceases. The liquor is afterwards decanted off, and the sediment, when washed, gives a paler colour. Greater intensity is given to indigo by adding a little potash. Yellow colours are given by turmeric dissolved in spirits of wine, by saffron, chrome-yellow, &c. Green colours are obtained by mixtures of blue and yellow; violets, by mixtures of red and blue, and by archil and a blue bath; lilacs, by archil only.

The method of making a rose will give a good idea of the manufacture in general. First of all the petals are cut out from the finest and most beautiful cambric. The pattern-shapes must be of different sizes, because in the same rose, the petals are never equal: a good assortment of patterns enables the artist the better to imitate the variety of nature. When the petals are thus prepared, they have to be dyed in a bath of carmine in alkaline water. For this purpose, they are held separately by means of pincers, and dipped first in the bath, and then into pure water, to give them that delicacy of tint which is characteristic of the rose. But as the colour of the petal usually deepens towards the centre, a tint is there laid on with the pencil, while a drop of water is laid on the point of insertion of the petal, to make the colour there fade off, as it does in nature, to white. If the right tint is not given at first, the processes are repeated: any slight imperfection, such as is seen in the petals of most living flowers, being also accurately imitated with the pencil. The taffeta employed in making leaves, is dyed of the proper green in the piece before cutting out. It is then stretched out to dry, and afterwards further prepared with gum-arabic on one side, to represent the glossy upper surface of leaves, and with starch on the other, to give the velvety appearance of the under side. This preparation, coloured to suit the exact shade to be given to the leaf, must be just of the proper consistence, making the leaf neither too stiff nor too limp, while it gives the proper kind of under surface. Where the leaf requires a marked degree of this velvet texture, it is given by the nap of cloth reduced to fine powder, and properly tinted. A little gum is lightly passed over the surface, and when partly dry, this powder is dusted over it, the superfluous portion being shaken off. These preparations having been completed, it yet remains to give to the leaves after they are cut out, the appearance of nature, by representing the veins and indentations which they always exhibit. For this purpose various gauffering-tools are made use of.

The material for the leaflets of the calyx in roses, is subjected to another process immediately on coming out of the dye, in order to preserve the firmness which it is necessary the calyx should have. To this end, the taffeta while still damp is impregnated with coloured starch on both sides, and stretched on the drying-frame: when perfectly dry, the leaflets are cut out according to pattern. Buds are made also of taffeta, or if partially open, they are made of white kid tinted of a suitable colour, stuffed with cotton, or crumb of bread, and tied firmly with silk to slender wires. The stamens are prepared by attaching to a little knot of worsted a sufficient quantity of ends of silk to form the heart of the flower. These ends of silk, cut to the proper length, are then stiffened in kid jelly, and when dry, the extremities are slightly moistened with gum-arabic and dipped in a preparation of wheaten flour, coloured yellow, to represent the pollen. Each thread takes up its separate grain and is left to dry. The heart of the flower being thus prepared, and fixed to a stem of wire, the smaller petals are arranged round it, and fixed by paste at their points. The larger petals succeed, some of which are hollowed or wrinkled, while constant care is taken to give them a natural appearance in disposing them around the centre. The calyx comes next, and encloses the ends of all the petals. It is fixed with paste, and surrounded with more or less of cotton thread, which also generally encloses one or more wires attached to that which bears the heart of the flower, and forming the germ. The whole is covered with silver-paper tinted green. The leaves are mounted on copper wire, and are arranged on the stem in the order which nature teaches, the covering of cotton and tissue-paper hiding the joints.

In addition to the manufacture of flowers intended as closely as possible to represent their living models, there is a large branch of the art in which the aim seems to be to depart from nature as far as possible. These *fancy flowers* are the fruit of the artist's peculiar taste, and are therefore as impossible to describe, as we sincerely wish they were impossible to execute. There are also flowers of natural forms, but of unnatural colours, being made to assume

mourning hues to suit the circumstances of their wearers. There are also gold and silver flowers, more resplendent, but equally unnatural. Of these, sometimes the stamens and pistils alone are metallic; sometimes the petals are gilded, and sometimes the leaves and fruit glitter in the same precious metal. An easy method of applying the gilt in any device or form, is to prepare a cement which shall fix it to the cambric, paper, or other material, (this cement may be honey and gum-arabic boiled in beer,) and then to moisten with it the surface, placing thereon rather more gold-leaf than is necessary to cover it, pressing it down with a cotton rubber, and when it is dry, rubbing off the superfluous gilding with the same.

Flowers are also made in chenille, but do not pretend to an accurate imitation of nature. There are two or three methods of making them, the simplest being to represent merely the shapes of flowers; for instance, apple-blossoms, represented by small loops of pink chenille arranged round a centre. Another method is, to make out the distinct petals, by rows of chenille placed close together. A third and prettier method, is that of uniting chenille with ordinary flower-making. Flowers made of feathers may be extremely rich and brilliant in their effect, as was proved by the beautiful bouquets in the Great Exhibition, and as may be observed in the flowers made of humming-birds' plumage in Mr. Gould's collection in the Zoological Gardens, Regent's Park. Yet ordinarily feather-flowers are more difficult than satisfactory, and there are very few of our own familiar flowers that can be successfully copied by them. One of the best imitations is that of the wild clematis when adorned as it is in autumn with its plumed seeds. These can be admirably imitated in white marabout feathers. Some of the most available feathers for flower-making, are those found under the wings of young pigeons.

The manufacture of wax flowers is carried on by using the purest virgin wax, entirely freed from all extraneous matters. Wax that is either granular or friable, must be rejected. It is generally melted in vessels of tinned iron, copper, or earthenware. To render it ductile, fine Venice turpentine, white, pure, and of an agreeable odour, is added. The mixture is constantly stirred with a glass or wooden spatula. All contact with iron must be avoided, and if the vessels are of that material, they must be well and carefully tinned. When stiff leaves are to be executed, two parts of spermaceti are added to eight parts of wax, to give transparency. Much care and tact are needed in colouring the wax. The colours being in fine powder, are made into a paste by adding little by little of essence of citron or lavender. When the trituration is perfect, this paste is mixed with melted wax, stirring rapidly all the while; and while the mass is still liquid, it is poured into moulds of pasteboard, or tinned iron, of the shape of tablets, and is then ready for use. Sometimes it is passed through fine muslin as it flows into the moulds. Another method is, to tie up the colour in a muslin bag, and wave it about amongst the molten wax until the desired tint is obtained. To combine colours, it is only necessary to have two or three bags containing different colours, and to employ as much of each as shall have the desired effect. These bags, far from being spoiled by dipping in wax already containing other shades, have only to be rinsed in pure water to fit them for colouring other wax. The colours most in use in wax flower-making, are pure forms of white-lead, vermilion, lake, and carmine, ultramarine, cobalt, indigo, and Prussian blue, chrome, Naples yellow, and yellow ochre. Greens and violets are chiefly made from mixtures of the above.

The wax being prepared, the manufacture of flowers is carried on in two ways. The first consists in steeping in liquid wax little wooden moulds rinsed with water, around which the wax forms in a thin layer, so as to take the form of the mould, and thus to present, when detached from it, the appearance of the whole or part of a flower. In this way lilac and other simple blossoms are obtained with much rapidity. The branches are also executed with wax softened by heat, and moulded with the fingers round a thread of wire. As for leaves and petals, they are cut out of sheets of coloured wax of the proper thickness. These sheets are glossy on one side, and velvety on the other. To express the veining of leaves, they are placed in moistened moulds, and pressed with the thumb sufficiently to get the impression, which is accurately copied from nature. The petals are made to adhere simply by pressure; the leaves are placed on a little footstalk, and the latter fastened to the stem. The manner of procuring moulds for the accurate imitation of leaves, is as follows:—A natural leaf of the plant it is wished to imitate, is spread out on a flat surface of marble, for example. It is lightly but equally greased with olive oil, and surrounded with a wall of wax, which must not touch it. Then in a small vessel containing a few spoonsful of water, a few pinches of plaster of Paris are to be thrown, and briskly stirred till the liquid has the consistence of thick cream. This is poured over the leaf, and left till it is well hardened. It is then lifted up and the leaf detached, when it will be seen that the plaster has taken a perfect impression of every vein and indentation. Such moulds are rendered far more durable if they are impregnated while warm with drying oil. This gives them greater solidity, and prevents their crumbling from frequent immersion in water. It is necessary to impress strongly on all amateur wax flower-makers, the necessity for having all tools and moulds completely moistened with water, otherwise the wax will be constantly adhering, and preventing neatness of workmanship.

The variety of the materials used in artificial flower-making, was displayed to an amusing extent in the Great Exhibition. In addition to the really beautiful and artistic productions already noticed, and to the elegant flowers constructed of palm-leaves, of straw, and of shells, as well as of all the materials named in this paper, there were flowers fabricated in human hair, in chocolate, in soap, in wood, marble, porcelain, common earthenware and other unpromising materials.

FLUE. See Chimney.

FLUID. See Hydrostatics and Hydraulics.

FLUIDITY. See Heat.

FLUOR SPAR. The word *fluor* is derived from the Latin *fluo*, to flow, in allusion to the important use of this spar as a flux. The Germans also name it *flus-spath*. Its chemical name is *fluoride of calcium*. It is found in great beauty and abundance in England, and especially in Derbyshire, where it is commonly called *Blue John*. It is usually found in cubic crystals, which admit of being easily cleaved into octohedra and tetrahedra by splitting it in the direction of its solid angles, as in Fig. 1006, which shows the octohedron resulting from the cube.[1] The colours of fluor spar are various: the spar is found perfectly limpid and transparent; also white, grey, and with various shades of blue, green, red, yellow, and purple. Its sp. gr. is 3. When reduced to small fragments and heated, fluor spar emits a phosphorescent light: the dark-blue variety exhibits a beautiful pale-green light, strong enough to be seen by day, but best seen in a dark room: the slightly-fetid variety shines with a purple tint; and one variety, which shines with a very brilliant green light, is on this account termed *chlorophane*. This phosphorescent property may be exhibited by sprinkling the crushed spar upon a hot shovel in a dark room, or by heating the spar in a platinum spoon over a spirit lamp. *Compact fluor* is harder than common fluor, and is sometimes granular in texture. That which is found at Stolberg in the Hartz is of a fine sky-blue colour, when first raised, but shortly, by exposure, becomes perfectly white. Indeed, the nature of the colouring matter of the blue and green spar is not understood. The workmen at Castleton, who make ornaments out of the Blue John, often find the colour so intense that the articles cannot be wrought thin enough to show it: they therefore gradually heat the stone in an oven until it is nearly red-hot, when the blue changes to an amethystine colour. By continuing the heat the colour entirely disappears. There is also an *earthy fluor*, which exhibits a friable texture.

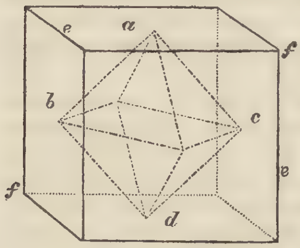


Fig. 1006.

The deep blue and purple varieties of fluor, found only at Castleton in Derbyshire, admit of being turned into vases, pateræ, and other ornaments. The stone is first roughed out with a point and mallet: then heated until it will fuse yellow resin, which is applied all over it: this penetrates about $\frac{1}{8}$ inch, and serves to hold the crystals together. It is next rough-turned, and a little hollowed; again heated, and resined and turned still more into form: it is next bound round with a thin wire, and again resined. These processes are continued until the spar is thin enough to show the colours: it is then resined for the last time, and polished. The only tool used is the steel point. The manufacture is a difficult one, since the spar, being an aggregation of crystals, all having a fourfold cleavage, the laminæ easily split and separate. Few, even of the best workmen, can turn very thin hollow articles.

(1) The new planes resulting from this *cleavage* of the crystal are called its *cleavage planes*. The line produced by the meeting of two planes is the *edge* of the crystal; and the meeting of any two lines or edges forms a *plane angle*. A *solid angle* is produced by the meeting of three or more plane angles. In Fig. 1006 *a b c d* are the exterior planes of the crystal; *e e*, its edges; *f f*, its solid angles.

FLUORINE, an elementary substance, (F. 19.) which has never been isolated in a state fit for examination. Compounds containing it can be decomposed without difficulty, and the fluorine transferred from one body to another; but so great is its affinity for the metals and for silicon, a component of glass, that in passing from one body it combines with the vessel containing it or one of its constituents. It is, however, from certain results that have been obtained, supposed to be gaseous, and, like chlorine, to possess colour. A compound of hydrogen and fluorine, hydrofluoric acid, has been used for etching on glass. By heating powdered fluor spar with concentrated sulphuric acid in a platinum retort, with a receiver of the same metal kept quite cold, a very volatile colourless liquid is obtained which emits copious white suffocating fumes in air. This is the anhydrous acid: it unites with water with much violence, and the dilute solution acts on glass with great ease. Dropped upon the skin, it is said to produce deep and malignant ulcers. For etching on glass the acid may be prepared in vessels of lead, which is but slowly acted on. Or the vapour of the acid may be applied in the following manner:—The glass to be engraved is coated with etching ground on wax, and the design traced in the usual way with a pointed instrument. A small quantity of powdered fluor spar is put into a shallow basin of sheet-lead, and enough sulphuric acid added to form a thin paste with the spar. The glass is placed upon the basin with the waxed side downwards, and a gentle heat being applied beneath, the vapour of hydrofluoric acid is speedily disengaged. In a few minutes the operation is complete: the glass is then removed, and cleaned with a very little warm oil of turpentine. The lines etched in this way are very clear and smooth. In the Great Exhibition some charming etchings on glass were exhibited from Prussian Saxony, and also from Belgium; the latter said to be by a new process.

FLUX, (from the Latin *fluo*, to flow.) Fluxes are of great use in the chemical arts. They are often required in cases of chemical action amongst metallic compounds at high temperatures. Their use is to protect the substance from the air; to dissolve impurities, which would otherwise be infusible, and to convey active agents, such as charcoal and reducing matter, into contact with the substance operated on.—See Copper, Iron, &c.

FLY-WHEEL. See Steam-Engine—Wheel.

FOCUS. See Lens.

FOIL, (from the Latin *folium*, a leaf.) Metallic foils, made of thin sheet-copper, silvered and bur-

nished, and afterwards coated with transparent colours mixed with isinglass-size, are often used by jewellers to improve the brilliancy of pastes and inferior stones. [See GEMS—JEWELLERY.] Copper-foil, also, called *Nuremberg* or *German* foil, is prepared by beating thin copper plates with a polished hammer, upon a well polished anvil, until the desired reduction is obtained: the copper is then heated in the fire between two thin iron plates; next boiled in a pipkin, in a solution of equal parts tartar and salt, constantly stirring until the surface becomes white: the foil is then dried, and again hammered. Care must be taken not to over-heat the plates in the fire, nor must they be boiled longer than is necessary to the white appearance. The polishing is then performed upon a very smooth plate of copper, about 1 foot long, and 5 or 6 inches wide, bent into a convex surface, fastened upon a half-cylinder, and fixed to a table. Some clean-washed whiting is then to be filtered through a clean linen cloth, and the copper wetted therewith: the foils are then laid on the convex surface, and polished with a polishing stone and the whitening until they are as bright as a mirror: they are then dried, and laid up secure from dust.

FOOD, PRESERVATION OF. The various organic substances furnished by the animal and vegetable kingdoms, which constitute the food of man, are, from the nature of their chemical structure, liable to change and decay: they are also irregular in their supply; hence arises the necessity of storing up the abundance of one season to meet the deficiencies of another. The art of preserving food as much as possible in its original state is therefore of great importance: it has been improved by gradual steps, depending, in great measure, as in so many other cases, on chemical discovery and the diffusion of chemical knowledge among persons engaged in the useful arts; so that, at the present time, the deprivations suffered by our forefathers may be prevented; the commonest articles of food may be enjoyed at all seasons; and even the delicious fruits of our gardens may be made to contribute to our health and refreshment at a season when the trees which produced them are covered with snow. The mariner, too, is not now necessarily confined to salt meats: he may, on the longest voyage, and in the severest clime, as easily enjoy fresh meat and vegetables as when he is in port.

The necessity for adopting means for the preservation of articles of food arises from the complicated structure of organic compounds, and their tendency to resolve themselves into simpler or inorganic compounds. Although the comprehensive history of the animal and vegetable kingdoms is written with a very brief alphabet; although the elements which enter into the composition of organic bodies are only carbon, hydrogen, and oxygen, often, but not always, nitrogen, and occasionally minute portions of sulphur and phosphorus; yet their extraordinary powers of combination are such that there appears to be no limit to the number of definite substances which they are capable of producing, each substance having a character peculiar to itself, and often a crystalline form. It is very different with the 58 other members of the list of elements; the compounds which they assist in forming are inorganic, and they are formed by the union of *pairs* of elements, or *pairs* of *binary* compounds. For example: copper and oxygen combine to form oxide of copper; potassium and oxygen form potash; sulphur and oxygen form sulphuric acid; sulphuric acid, in its turn, combines with oxide of copper, forming sulphate of copper, and with oxide of potassium, forming sulphate of potash; and even these two salts may be formed into a double compound, expressed by the formula $CuO, SO_3 + KO, SO_3$. In this way the most complicated inorganic products may be produced by repeated pairing on the part of their constituents. No such arrangement can, however, be traced in the structure of organic bodies. Sugar is composed of $C_{12}\,H_{11}\,O_{11}$; starch, $C_{24}\,H_2\,O_{20}$; albumen, or white of egg, has the highly complex formula, $C_{400}\,H_{310}\,N_{50}\,O_{120}\,PS_2$; while the salt which is necessary to give it flavour, is expressed by the simple formula Na Cl.

It is a consequence of this complicated structure, that organic compounds are unstable in their character, and liable to decomposition, or, in other words, to resolve themselves into simpler compounds. An inorganic substance, on the contrary, however complex its formula may appear, is actually built up of binary compounds, the simplest that can be formed. But in the organic substance the carbon and hydrogen have a strong tendency to form carbonic acid; the hydrogen and oxygen to form water; the hydrogen and nitrogen to form ammonia; or the hydrogen and the sulphur to form sulphuretted hydrogen, &c. In popular language, these changes are expressed by such terms as *decay* and *putrefaction*. Liebig, however, has given precision to them by limiting the term *decay* to the decomposition of moist organic matter freely exposed to the air, the oxygen of which gradually burns and destroys it without sensible elevation of temperature.[1] The term *putrefaction* is limited to changes which occur in and beneath the surface of water, the effect being a mere transposition of elements or metamorphosis of the organic body.[2] The conversion of sugar into alcohol and carbonic acid is a simple illustration of the term. The contact of oxygen is, however, first necessary to the change, which, when once begun, is continued without the aid of any other external substance, except perhaps water, or its elements. Every instance of putrefaction begins with decay; and if the decay or its cause, viz. the absorption of oxygen, be prevented, no putrefaction occurs. In short, if the access of oxygen be

(1) Hence the term employed by Liebig and his followers, *eremacausis*, or *slow-burning*.

(2) "The colourless fresh-cut surfaces of a potato, of a turnip, or of an apple, when exposed to the air, soon become brown. In all such substances the presence of a certain quantity of water, by which the molecules are enabled to move freely on one another, is a condition necessary to the production, by temporary contact with air, of a change in form and composition, a resolving of the original body into new products, which continues uninterrupted till no part of the original compound is left. This process has been distinguished by the name of *putrefaction*."—*Liebig.*

prevented, there is no decay; if the access of water be prevented, there is no putrefaction. The exclusion of air and moisture forms the basis of some of the best methods of preserving food.

There are certain substances named *Antiseptics*, (from ἀντὶ, against, and σήπομαι, to putrefy,) from their property (exerted, however, very unequally) of preventing the putrefaction of organic substances. Thus, alcohol and common salt in certain proportions, check all putrefaction and all the processes of fermentation by depriving the putrefying body of water. Nitre, vinegar, spices, and sugar are also antiseptics. The antiseptic effect of a very low temperature is caused by the solidification of the water and other juices, which, in their usual fluid state, allow the molecules to move freely on one another.

We will first notice the various methods of preserving animal food; these are:—1. by drying; 2. by cold; 3. by salting and by sugar; 4. by smoking; 5. by vinegar; 6. by parboiling and excluding air; 7. by potting; 8. by alcohol.

1. A familiar example of the first method is afforded in common glue, which in its hard and dry state may be kept for any length of time. So also may white of egg, if prepared in the manner directed for fining coffee. [See COFFEE, p. 409.] These two substances, *gelatine* and *albumen*, are two of the constituents of flesh; *fibrin* or *fleshy fibre*, which is the third, dries equally well, and is not liable to putrefaction in that state. Gelatine, after being dried, may be softened by the action of hot water. Albumem *coagulated* by heat cannot be softened again by water; but if dried at about 140° without being coagulated, it may be dissolved in cold water, retaining all its valuable properties. Hence, in preserving meat by drying, too high a temperature must be carefully avoided, or the albumen will become coagulated, and the meat be made insoluble.

The dried flesh of the bison, of the buffalo, and of the deer forms *pemmican*, the preparation of which is thus described in Captain Back's Journal:—

"While meat remains in a thick piece, it is impossible to get the middle dried before putrefaction commences; but if the meat be cut into slices, its desiccation may be easily effected. The fleshy parts of the hind quarters are cut into very thin slices, dried in the sun, or before the fire, and pounded. Two parts of the pounded meat are then mixed with one of melted fat, and packed into a bag formed of the hide of the animal. A bag weighing 90 lbs. is called a *taureau* by the Canadian voyageurs; and in fact, only one bag of pemmican is generally made from each bison cow. Two pounds of this kind of food are sufficient for the daily support of a labouring man; though, when the voyageurs first commence upon pemmican, they each consume 3 lbs. or more. In the spring, they generally boil the young shoots of the *Epilobium angustifolium* with it, and some Scotchmen in the service of the Hudson's Bay Company, add flour or oatmeal, thus rendering it more palatable. The best pemmican is made of finely pounded meat mixed with marrow, and further improved by the addition of dried berries or currants. If kept from the air, it may be preserved sound for several years, and being very portable, it might be used with great advantage in provisioning troops that have to make forced marches. It may be eaten raw, or mixed with a little water and boiled; and although not much relished by those who taste it for the first time, the voyageur, with the single addition of the luxury of tea, requires nothing else for breakfast, dinner and supper."

In the West Indies, and in South America, jerked beef is prepared by cutting the meat into slices, dipping them into sea-water or brine, and then drying them in the sun. The flesh of wild cattle is thus preserved at Buenos Ayres. Sometimes this dried meat is pounded in a mortar, into a uniform paste, which is pressed into jars, and if intended to supply the wants of the traveller, it is beaten up with maize meal and packed closely in leather bags. It is eaten in this state without further cooking. Drying meat in the air is said, however, to injure its flavour, and to dissipate a great portion of the nutritious juices.

Some kinds of fish are preserved by slitting them down the middle, and drying them in the air to evaporate the moisture. Small cod, haddock, and stock fish, prepared in this way, will, if kept dry, remain good for a great length of time.

Portable soup is prepared by processes similar to those used in the manufacture of glue. [See GLUE.] The gelatine of meat is dissolved by boiling water, and the water being evaporated, the gelatine is left in a solid state. Any fresh lean meat, with the fat cut away, will answer the purpose. Bones are also used for the purpose, [see BONE,] the gelatine being extracted by means of a digester. [See DIGESTER.] In the French manufacture of *gelatine brut fin*, 100 lbs. of bones yield about 25 of gelatine, which is dried, cut up into dice, and used for making soup.

2. The effect of cold in the preservation of animal substances received a remarkable illustration in the discovery made by Pallas, in the year 1779, on the shores of the Frozen Ocean, near the mouth of the river Lena, of an animal of immense size, imbedded in ice, which, as it melted gradually, exposed it to the air and furnished food for the hungry wolves and other animals of those regions. It was the opinion of Cuvier, that this animal differed from every known species of elephant, and was antediluvian, preserved from the remote period of the deluge in the mass of ice which enveloped it. Some of the hair of this animal may be seen in the museum of the Royal College of Surgeons, in Lincoln's Inn Fields.

In Russia, Canada, Hudson's Bay, and other countries where the frost is sufficiently steady, meat preserved in this way is a common article of commerce. Travellers speak with admiration of the frozen markets of Russia, supplied as they are from distant places with provisions solidified by the cold. Thus, in the market at Petersburg, Mr. Kohl noticed partridges from Saratoff, swans from Finland, heath-cocks and grouse from Livonia and Esthuria, while the wide Steppes furnished the trapp-geese which flutter over

their endless plains, where the Cossack hunts them on horseback, and kills them with his formidable whip. All these birds, as soon as the life-blood has flown, are apparently converted into stone by the frost, and, packed in huge chests, are sent for sale to the capital. So rapid are the effects of frost in that country, that the snow-white hares which are brought in sledge-loads to the market, are usually frozen in the attitude of flight, with their ears pointed and their legs stretched out, just as they were at the moment of death. Another curious sight in these markets is a frozen rein-deer, its knees doubled under its body, its hairy snout stretched forth upon the ground, and its antlers rising majestically in the air; or a mighty elk, disappearing piece by piece, as the action of the saw and the axe separates it for distribution among the several customers.

When provisions have been frozen, great care is required in thawing them; for if this be done suddenly, putrefaction soon sets in, and although cooked immediately, they are hard and deficient in flavour. They must be thawed by immersion in cold water.

The London markets are supplied with salmon packed in ice from many of the northern rivers that flow to the eastern coasts of Britain. Every salmon fishery is now provided with an ice-house, and a stock of ice collected during the winter. The salmon is packed in large oblong wooden boxes, with pounded ice between, and the fish is received in London as fresh as when it was taken out of the water. It is not, however, frozen. Most fishmongers are furnished with ice-houses or cellars for the preservation of their fish in tubs of ice; and we do not see why butchers should not be provided with larders cooled by the same means. In many parts of the United States every housekeeper has a small ice-safe, in which, through the warm season, all kinds of perishable provisions are kept. Public ice-houses are also maintained by the butchers, so that under the burning climate of South Carolina there is less loss in the way of butcher's meat, fish, game, &c., than in the comparatively temperate summer of our own metropolis. The meat is sent to the ice-house near the market, every evening, and is cooled down to near the freezing point during the night; when exposed on the stalls next day it retains its low temperature for a long time. Such a plan, adopted in London, would prevent the immense waste of meat during every summer, which is said to amount to at least 2,000 tons in London alone. It is true that when meat has been once frozen its flavour is injured, but the reduction of meat to 32° or thereabouts, and the solidification of its juices, are very different things: and it would be easy to regulate the temperature within a range of several degrees. [See Ice.]

3. Various kinds of salt are used in the preservation of food, these will be described in our notice of Salt. Saltpetre and sal-prunella (which is saltpetre deprived of its water of crystallization by heat) are also used for the purpose. The action of these alkaline salts upon animal substances is, as already noticed, to abstract the water in the juices of the meat, and being dissolved therein, the salts enter the pores of the animal substance; the albumen of the meat, which is more liable to putrefaction than the gelatine and fibrine, is thus rendered less so. There are two methods of salting, *dry-salting* and *pickling*. In dry-salting, the meat is packed in dry salt, or in some cases the surface is rubbed all over with salt. In pickling, the meat is kept immersed in a solution (sometimes saturated) of common salt dissolved in water. This method does not render the meat so salt as dry rubbing, and is probably less injurious to its nutritious qualities, but it will not keep the meat so well. Bacon is *cured* by salting and drying, for which latter purpose it is often hung up in the wide chimneys of farm-house kitchens; cod is also salted and dried for the large demand of the Peninsula; in England, it is used in a *green* state; that is, instead of being split quite open, it is only opened down to the navel, then salted, and laid in brine or strong pickle, and put into casks without drying. Haddock, cod, or ling, are cured by splitting the fish and removing the back-bone; they are then salted for two or three days, with equal parts of salt and sugar, or with salt alone; they are next stretched on sticks, and laid on the beach to dry in the sun, or they are arranged on stages, or hung up in an enclosed space warmed by a stove. Herrings are salted or pickled, and smoked.

Sugar, like salt, takes away the water from animal substances, and thus prevents putrefaction. By immersing meat in molasses, it has been preserved fresh for months. Fish is sometimes preserved by cutting it open, rubbing in sugar, and leaving it for a few days; it is then dried in the air, taking care to turn it frequently. For a salmon of six pounds weight, a table-spoonful of brown sugar is sufficient; but if hardness be required, a teaspoonful of saltpetre is to be added.

4. The efficacy of *smoking*, or *smoke-drying*, arises not only from the heat of the smoke, but from certain chemical products disengaged during the combustion of the wood fuel used for the purpose. Pyroligneous acid vapour and kreosote are both produced, and the latter substance possesses the remarkable property of coagulating albumen. Hence, those chimneys only are fit for the purpose where the fire below is wood or peat, not coal. The kind of wood burnt is also of importance, the smoke from beech and oak being preferable to that from fir or larch. Smoke from the twigs of juniper, rosemary, peppermint, &c. impart to the meat a portion of their aromatic flavour. Westphalia hams owe some of their excellence to being smoked by juniper. Slow smoking is preferable to rapid, as it penetrates completely into the interior of the meat. In some parts of the country, the drying and smoking of hams is a separate trade, a charge of 4*d.* or 6*d.* per ham, and 1*s.* for a flitch, being made. In such cases, a smoking-house or hut is erected, about 12 feet square, and the walls 7 feet high, with a hole in the roof; joists are laid across inside, to hang the flitches on, and the floor is covered 5 or 6 inches deep with saw-dust, which being kindled, produces much smoke and little flame.

5. Vinegar and some other acids preserve both animal and vegetable substances by coagulating their albumen, which, as already stated, is peculiarly liable to putrefactive fermentation.

6. In the year 1810, M. Appert received a reward of 12,000 francs from the French Government for his method of parboiling provisions, and enclosing them in earthenware vessels in such a manner as to exclude the air.[1] Many vegetables, fruits, &c., can be kept fresh for a great length of time, by shutting them up closely in a vessel, having previously filled up the interstices with sand or other loose substance that will exclude nearly all the air. Fresh walnuts may be preserved in this way in a jar, packed with sand and closely covered over; grapes packed in sawdust are imported into England from the Peninsula. Meat cannot be preserved in this way, but by exposing it to the heat of boiling water, the albumen, in which putrefaction first commences, coagulates; and as coagulated albumen is somewhat slow in decomposing, we thus have a reason for the common observation that cooked meat will keep longer than raw. It will not, however, keep many days, unless the air be perfectly excluded, not only from the external, but from the internal parts. The air in the interior may be expelled by boiling, and the exterior air may be kept away by enclosing the substance in an air-tight vessel. If these conditions be carefully observed, food may be preserved for any length of time. Appert's method consists in applying heat to the substances to be preserved, so as to coagulate their fermentable juices, and then to place them in such a situation as to deprive them of contact with air. The vessel in which the meat is prepared, is plunged for some time into boiling water before it is finally sealed, in order to drive out the last portions of the air; for if a small portion of oxygen gas were present, this would be sufficient to commence the process of fermentation, and when once begun it would be continued.

Messrs. Donkin & Co. took out a patent in this country for M. Appert's process, which, as improved by them, may be described as follows:—

The meat to be preserved is first parboiled, or somewhat more, and freed from the bones. It is then put, together with vegetables, if required, into tin cases or canisters, which are filled quite up with a rich gravy; a tin cover with a small aperture in it is then carefully fixed on to each canister by solder, and while the vessel is perfectly full, it is placed in boiling water, or in a saline bath, heated above the boiling point of water, and kept therein until the air has been expelled as completely as possible by the steam generated within the canister. The small hole in the cover is completely closed up with a little solder while the contents are yet hot, the issue of the steam being stopped for a moment by means of a damp sponge. The canister with its ingredients is now allowed to cool, in consequence of which these contract, and the sides of the vessel are forced slightly inwards by the pressure of the atmosphere, and become a little concave. As a precautionary measure, however, the tins are placed in the testing-room, which is heated to above 100° Fahr.: should putrefaction take place in consequence of a minute portion of oxygen left in the case, and not combined with the animal or vegetable matter, the generated gases will burst the canisters; those, however, which withstand this test, will preserve the provisions for many years; for as each vessel is hermetically sealed, and all access of air prevented, it may be sent into any climate without fear of putrefaction, and the most delicate food of one country be thus eaten in its original perfection in a distant region, many months or even years after its preparation. In this manner may all kinds of alimentary substances be preserved; beef, mutton, veal, and poultry; fish and game; soups, broths, and vegetables; creams and custards. Of a quantity taken by Captain Nash to India, not one canister was spoiled; and one which he brought back contained, after two years, beef, in the highest state of perfection and preservation, and after having been carried upwards of 35,000 miles, in the warmest climates. This method has been adopted by the Commissioners for victualling the Navy, who, having examined some meat so preserved for four years, during voyages in the Mediterranean and to America, found it as sound, sweet and fresh, as if it had been boiled only the day before. Captain Basil Hall bears similar testimony. It was stated, however, by the officers in the Antarctic voyage, that they gradually got very tired of preserved meats, but not of preserved vegetables, and that there was an insipidity in them which they did not find in fresh food. There is, however, no doubt that if the articles be selected with care, and the process be properly conducted, M. Appert's method of preserving food is a valuable invention. If the contractor be careless or dishonest, the most fearful consequences might ensue to the crews of ships victualled with preserved meats. It appears from a recent examination of several thousand canisters of the preserved meat of the Navy at Portsmouth, that their contents were masses of putrefaction, consisting of meat, coagulated blood, pieces of liver, intestines, ligaments, &c., which, even in a fresh state, ought never to be used as food. It is stated that this preserved meat was supplied from Galatz, in Moldavia.

In 1842, M. Appert's method was made the subject of a further patent, granted to Mr. Bevan, whose process consisted in expelling air from the cases containing the food, by placing such cases in connexion with a vacuum chamber, or other exhausting apparatus, and also with a vessel containing gelatine or other suitable fluid material, in such a manner, that by opening the communications, the air escapes into the exhausting apparatus and the gelatine takes its place. By this method the high temperature previously used in preserving food was not required; it could, on the contrary, be cooked at very low temperatures, and in a space almost void of air. The appa-

(1) M. Appert's method is described fully in a small volume entitled, "Le Livre de tous les Ménages, ou l'art de conserver pendant plusieurs années toutes les substances animales et vegetales." A fourth edition of this book was published in 1831.

ratus used is shown in section, Fig. 1007. A is a vessel open at the top, and filled to the line *i* with fluid gelatine, having a pipe *j*, and a stop-cock *e* firmly attached to it. B is a sphere of metal in which a

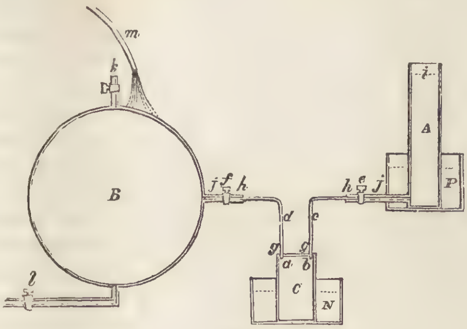


Fig. 1007.

vacuum is produced by blowing steam through it by the pipe *l* out through *k*: *l* and *k* are then closed, and a jet of water at *m*, applied to the outside of the sphere, condenses the steam and leaves a vacuum within it. The substance to be preserved is enclosed within a cylindrical tin vessel C, the top of which is then soldered on, and two small metal pipes *d* and *c* passed into it air-tight, as far as *a b*; the other ends being secured to the pipes *j j* at *h h*. The case is next immersed in a water bath N, at a temperature of about 120°, and by turning the cock *f*, the greater portion of the air in the case C rushes into B; the article of food, animal or vegetable, in the case, being thus relieved of atmospheric pressure, the heat of 120° is sufficient to cook it, and to expel the air from it. A fowl is cooked in this way in about 15 minutes. The cock *e* is then opened, and the gelatine, kept fluid by the warm bath P, enters by the pipes *j* and *c*, into the case C, and drives the small portion of air left therein into the vacuum chamber B. The case C is then hermetically sealed by nipping the tubes *d* and *c* at the points *g g*. The case is then submitted for a few minutes to the action of boiling water, (30 minutes for a fowl,) and when cool, the process is complete.

A concentrated form of food, called *meat biscuit*, excited a considerable degree of attention in the Great Exhibition. It is formed by boiling down the fresh beef of Texas, and mixing into the strong beef-tea thus formed a certain proportion of the finest flour. The biscuit formed from these materials is so nutritive, that less than four ounces a-day (mixed with warm water or not, according to circumstances,) is sufficient food for a man in active service. It is very light and portable, and keeps perfectly well without change: hence it is admirably adapted to the provisioning of troops, ships, and overland expeditions. The manufacture is also of great importance to those countries in which cattle are superabundant, and are killed merely for the sake of their skins for the tanner, or their bones for the farmer, the flesh being actually thrown away. In some places, animals which we are accustomed to regard as valuable, are so numerous that they are drowned by hundreds, merely to get rid of them, neither their skins, bones, nor flesh serving as a pretext for the wholesale slaughter.

Milk has been preserved in the following manner:— Fresh milk is reduced by boiling to one-half, and beaten up with yolk of eggs, in the proportion of 8 eggs to every $10\frac{1}{2}$ quarts of milk. The whole is then placed on the fire for half an hour, and skimmed frequently; it is next strained and heated in a water-bath for two hours. It is stated that this milk will keep good for two years, and if churned, would afford good butter. Cream may be preserved by boiling five measures down to four; then, after cooling and skimming, it is put into a bottle, corked down, luted, and kept in the boiling heat of a water-bath for half an hour. This, it is said, will keep two years.

A much better method of preserving milk is that first pointed out by M. Dirchoff, the Russian chemist, namely, to solidify it by driving off the aqueous portion by a gentle heat. Specimens of consolidated milk were shown in the Great Exhibition; and it was stated, that after being dissolved in boiling water, and reproduced in the form of milk, the solution will keep pure for four or five days. As milk contains 873 parts water in every 1,000, it follows that 1,000 parts of milk will yield by evaporation only 127 parts.

7. *Potting* is only another contrivance for excluding animal substances from contact with air. Lean meat should be selected, cooked, and then reduced to a pulp by being beaten in a mortar, salt and spices being incorporated. The pulp is then rammed into jars, and preserved from the air by a thick coating of melted butter or lard, poured over it.

In the preservation of fruits and vegetables, some are dried, as in the case of nuts, raisins, sweet herbs, &c.; others are preserved by sugar, such as many of the fruits, whose delicate juices would be dissipated in the process of drying. Some are preserved in vinegar, as in the case of pickles; a few by salting, as French beans; and others are preserved in spirits.

Appert's method applies to vegetables and fruits of all kinds; they need not, however, be parboiled. The dry and fresh-gathered fruits are put into strong, wide-mouthed glass bottles, carefully corked, and luted with a cement of lime and soft cheese, and bound down with wire. The bottles are then enclosed separately in canvass bags, and put into a kettle of water, which is gradually heated until it boils; the bottles are kept in this condition until the fruits are boiled in their own juice. The whole is then left to cool; after which the bottles are examined separately, and put away for store.

Many kinds of vegetables may be preserved by being spread out on the floor of a kiln, and dried by a gentle heat: the thicker kinds of roots, such as carrots, turnips, potatoes, &c., are to be sliced, and thoroughly well dried; after which, they must be packed up in paper or very dry boxes, and put into casks.[1]

(1) The flour and biscuit which are taken out to sea in the British navy are packed in casks of wrought-iron. These were formerly painted, to prevent rust, and also to make them water-tight; but the paint was found to give a bad taste to the flour, &c.,

A method of preserving vegetables by drying and pressure, recently invented by M. Masson, was brought into prominent notice at the Great Exhibition. Cabbage, sliced turnips, apples, or whatever vegetable be selected, is dried in an oven at a certain temperature, so as to drive off from 7 to 8 per cent. of water: the drying must not be conducted too slowly nor too rapidly, but at a medium rate. After the drying, the vegetables are packed into a very small compass by the intense pressure of a hydraulic press; then squared and trimmed with a knife, packed up in tin-foil, and lastly, stored in boxes. A short time ago, we examined some red cabbage preserved in this way, which had been exposed in the Great Exhibition all the time it was open, and had been slowly absorbing moisture, and yet it appeared to be perfectly good. By this method, from 15,000 to 18,000 rations, of $\frac{1}{4}$ lb. each, can be stowed into a cubic yard. We also saw some dried plantains from Mexico, (a vegetable of very considerable nutritious value,) which had been lying in a warehouse at Woolwich ever since the year 1835, and had undergone no change. It was stated that the method of preparing them is cheap and easy, and that the dried plant can be sent in any quantities to Europe, at 3*d.* per lb., with a considerable profit to the importer.

Some kinds of vegetables, such as French beans, artichokes, olives, samphire, and barberries, are preserved by salt, a strong brine being made by the addition of four pounds of salt to a gallon of water; the vegetables are put into this, and quite covered with it. In Holland and Germany, kidney-beans are sliced by a machine something like a turnip-cutter, and put into a cask in layers with salt between; a weight is then put on, and pressure is kept up until a slight fermentation takes place; the salt liquor is then poured off; the cask is covered up, and put into the cellar as store. Before being cooked, the beans are steeped in fresh water.

Sauer Kraut is prepared somewhat in the same manner. The following recipe for making it is given by Parmentier:—

The heads of white winter-cabbages, after removing the outer leaves, are to be cut into fine shreds, and spread out upon a cloth in the shade. A cask which has had vinegar in it is to be selected, or if that cannot be had, the inside should be rubbed over with vinegar, or sauer-kraut liquor. A layer of salt is to be put in the bottom of the cask, caraway-seeds are to be mixed with shreds of cabbage, and they are to be packed in the cask to the depth of four or six inches; and layers of this kind, with salt between each layer, are added till the cask is full, stamping them down with a wooden stamper as they are put in, to half their original bulk; some mix a little pepper and salad oil with the salt. Some salt is to be put on the top, and some of the outside leaves of the cabbages. About 2lbs. of salt suffice for 20 middle-sized cabbages. The head of the barrel is to be placed upon the cabbage-leaves, and must be loaded with heavy stones. A common method is for a man, with clean wooden shoes on, to tread the cabbage down in the cask. Fermentation will take place, and some juice will be given out, which is green, muddy, and fœtid: this rises to the surface, and is to be replaced with fresh brine. When the fermentation is over, the casks are closed up. Cabbages are preferred, but any other vegetables may be treated in the same manner.

When vegetables are preserved in vinegar, they form *pickles.* When sugar is the preserving medium, they are variously named according to the mode of preparation. Fruits, flowers, herbs, roots, and juices, boiled with sugar or syrup, and employed in pharmacy, as well as for sweetmeats, are called *confections* (Latin, *conficere*, to make up). *Liquid confects* consist of fruits, either whole or in pieces, preserved by immersion in fluid transparent syrup: apricots, green citrons, and some foreign fruits, are treated in this way. *Dry confects* are prepared by boiling in syrup those parts of vegetables adapted to this method, such as citron and orange-peel, &c.; they are then taken out and dried in an oven. *Marmalades, jams,* and *pastes* are soft compounds made of the pulp of fruits, or other vegetable substances, beaten up with sugar or honey: oranges, apricots, pears, &c., are treated in this way. *Jellies* are the juices of fruits,—currants, gooseberries, apples, &c.—boiled with sugar to such a consistence as, on cooling, to form a trembling jelly. *Conserves* are dry confects, made by beating up flowers, fruits, &c. with sugar not dissolved. *Candies* are fruits candied over with sugar after having been boiled in the syrup.

The best syrup for preserving fruits is made by dissolving two parts of double-refined sugar in one part of water, boiling a little, skimming, and filtering through a cloth. This gives a good smooth syrup, which does not readily ferment nor crystallize.

The specimens of preserved food in the Great Exhibition were exceedingly numerous: they included animal and vegetable productions, fruits, &c. One interesting specimen was a canister containing boiled mutton, prepared by the exhibitor, Mr. Gamble, for the Arctic Expedition in 1824. A large number of these canisters were landed from H. M. S. *Fury*, on the beach where the ship was wrecked in Prince Regent's Inlet, and were found by Captain Sir John Ross in August, 1833, in a state of perfect preservation, although annually exposed to a temperature of 92° below, and 80° above zero. Had it not been for the large store of provisions left by Parry near the spot where the *Fury* was wrecked, Ross's expedition must have perished.

FORCE. See MECHANICS.

FORGE—FORGING. Some of the varied manipulations of the forge, concerned in the production of small articles in iron and steel, are described in the article CUTLERY. In the present article a few details will be given respecting the forging of large articles; but we must also refer to IRON and STEEL for further information; inasmuch as the process of forging may be said to commence as soon as the *ball* of iron is

and they are now coated outside with a waterproof composition of caoutchouc, black resin, and Venice turpentine.

taken out of the puddling-furnace, and receives its first blow from the helve, in the process of converting it into a bloom.

In addition to the ordinary business of a large iron-work, which consists in the production of bar, plate, and hoop-iron, the hammer-men are also employed in preparing masses of metal or *uses*, several of which are *used* or welded together in the construction of a large work. For example, in the forging of a square shaft, as many as from ten to twenty square pieces of iron may be bound together, and put into a powerful air-furnace, the ends of the bundle being welded together by a hammer weighing five tons; after which the weld is extended throughout the length. The paddle-shafts of the largest steam-ships are formed by successive additions at the end of a mass of iron: for instance, a slab or *use* is welded on one side near the end, and both are hammered or *drawn* down to the common thickness, so that the additional matter is thrown into the length: another slab or *use* is added to the adjoining side of the as yet square shaft, and also drawn down into the length; and so on, until the proper size is attained. In the paddle-shafts built by Messrs. Maudslays for the *Great Western* steam-ship, consisting of three pieces connected by drag-links, the middle length was 12 feet long; the two outer, or the paddle-shafts, each 22 feet long; the largest, or central diameter, was 18 inches; they tapered off to 12 inches at the external parts, and the bearings were 16 and 15 inches diameter. The weight of the three pieces was nearly 20 tons, and their value before they left the forge was upwards of 1,000*l.*

In the forging of such heavy works, Nasmyth's steam hammer is now principally used, and the ponderous masses of red-hot metal are managed with wonderful facility. "First, the *heat* has a long iron rod attached to it in continuation of its axis, to serve as a *porter* or guide-rod. The mass is suspended under a traversing crane, at that point where it is nearly equipoised, and the crane not only serves to swing it round from the fire to the hammer, but the traverse motion also moves the work endways upon the anvil, and small changes of elevation are sometimes effected by a screw adjustment in the suspending chain. The circular form is obtained by shifting the work round upon its axis by means of a cross lever fixed upon the porter, and moved by one or two men, so as to expose each part of the circumference to the action of the helve: this is readily done, as the crane terminates in a pulley, around which an endless band of chain is placed, and the work lies within the chain, which shifts round when the work is turned upon the anvil. The precision of the forgings produced by these means is very surprising." [1]

Smaller works are also forged in a somewhat similar manner. Several bars are often piled together and *faggoted;* that is, a round bar in the centre is surrounded by a group of bars of angular section, called *mitre-iron*, and are wedged together in a hoop. Or *scrap-iron* is used; that is, the odd scraps and refuse of a variety of works are enveloped in an old piece of sheet-iron, and held together by a hoop: the mass is raised to the welding heat in a blast or air-furnace, and the whole is consolidated and drawn down under the tilt hammer; one long bar, to serve as a porter, being welded on by the first blow. [See GUN.]

In heavy works of somewhat complex form, such as anchors, hand forging is found most convenient. As this is very laborious work, two gangs, of six or twelve men each, are employed, who relieve each other at short intervals. Each man is armed with a heavy sledge-hammer, and the hammers are all swung round and made to fall upon any one particular spot with remarkable regularity, the blows being directed by a foreman with a long wooden wand. Square shanks of anchors are also partly forged under a vertical hammer, called a *monkey*, consisting of a long iron bar running loosely through an aperture several feet above the anvil, and terminating at the foot in an iron ram. This hammer is elevated by a chain attached to the rod and also to a drum above, which is put in gear with the engine, and suddenly released by a simple contrivance when the hammer has reached the height of from 2 to 5 feet. The ram is made to fall upon any point indicated by the foreman's wand, as it has a horizontal range of about 20 inches from the central position, and is guided by two slight gye rods hooked to the ram, and placed at right angles: these gyes are held by two men who watch the motion of the foreman's wand.

Shovels, spades, mattocks, cleavers, and other implements and tools are partly forged under the tilt-hammer. We shall have occasion to notice the subject of *tilting* in the article STEEL.

Works of large size are heated in air furnaces, as already noticed. When they are short and complex in figure, the open fire or smith's hearth is used. The largest kind of smith's hearth is a trough or pit of brick-work, about 6 feet square, elevated about 6 inches from the ground: one side of the hearth is extended into a vertical wall leading to the chimney, the lower end of which terminates in a hood of stout plate-iron for collecting the smoke. The back wall of the forge is fitted with a large cast-iron plate or *back*, in the centre of which is a thick projecting nozzle of iron, perforated, and forming what is called a *tuyere*, for admitting the blast which urges the fire. The blast may be supplied from bellows, by a revolving fan, or by one of the methods described in BELLOWS AND BLOWING MACHINES.[2] The cast-iron back is liable to crack from the heat: to prevent this, it is made hollow, and a stream of water from a small cistern allowed to circulate through it; or air in its passage from the blowing apparatus is passed through it, and thus a *hot blast* is formed. The forge used in forging small works is described under CUTLERY.

FORK. See CUTLERY.

FORMIC ACID. In our notice of ACETIC ACID it was shown that alcohol, by oxidation, under the influence of finely-divided platinum, produces acetic acid. When wood spirit ($C_2H_3,O + HO$) is exposed

(1) Holtzapffel: Mechanical Manipulation, vol. i.

(2) A portable forge is described in this article.

under similar circumstances, a peculiar acid is produced, by the substitution of two equivalents of oxygen for two of hydrogen. This acid is named *formic* (C_2HO_3), from the circumstance of its having been first found in the bodies of ants. The hydrated acid ($C_2HO_3 + HO$) is a clear colourless liquid, which fumes slightly in the air; it has a very penetrating odour; it boils at about 212°: when cooled below 32° it crystallizes in large brilliant plates. Its sp. gr. is 1·235: it mixes with water in all proportions; the vapour is inflammable, burning with a blue flame. There is a second hydrate containing two equivalents of water: its specific gravity is 1·11, and it boils at 223°. In its concentrated form it is very corrosive. A more dilute acid may be prepared by heating starch sugar and other organic substances with oxidizing agents. Formic acid may also be obtained by distilling ants with water, or simply by macerating them in the cold liquid. The salts formed by this acid with bases are termed *formiates*. The chemical relations of formic acid will be further noticed under PYROLIGNEOUS ACID.

FOUNDATION. See BRIDGE—BRICKLAYING.

FOUNDING. See CASTING.

FOUNTAIN. See ARTESIAN WELLS.

FRAMING. See CARPENTRY—FLOORS AND PARTITIONS.

FRANKFORT BLACK. See CARBON, p. 316.

FRANKINCENSE, common, is the spontaneous exudation of *Abies communis:* it concretes into yellow drops or tears. It is a vegetable hydrocarbon. For the genuine *thus*, or frankincense of the ancients, see OLIBANUM.

FREESTONE, a term applied to such of the sandstones used for building as work *freely* under the tools. See SANDSTONE.

FREEZING. See HEAT.

FREEZING POINT. See THERMOMETER.

FRENCH POLISH consists of a resin or a gum-resin dissolved in spirit, and used for polishing flat surfaces. For this purpose it is made more fluid than the hardwood lacker, used in polishing turned surfaces, in order that it may spread easily and dry less rapidly; because the friction being derived entirely from the motion of the hand, more time is required than in polishing turned works.

The recipes for making French polish are innumerable. Indeed, it is seldom prepared in the same manner by two different makers. Some prefer it very thin, others tolerably thick; some, of one colour; some, of another; while others make it colourless or nearly so. The simplest method is to dissolve $1\frac{1}{2}$ lb. of shell-lac in 1 gallon of spirits of wine without heat. Copal, sandarac, mastic, and gum arabic are sometimes used in various proportions, according to the fancy of the preparer. Some recommend 12 ounces of shell-lac, 6 ounces of gum arabic, and 3 ounces of copal, to 1 gallon of spirits of wine. A dark-coloured polish is prepared with 1lb. of shell-lac, $\frac{1}{2}$lb. of benzoin, and 1 gallon of spirits; or $1\frac{1}{2}$lb. shell-lac, 4 ounces of guaiacum, and 1 gallon of spirits. Dragon's blood may also be used to give the required tint.

The hardest and most durable polish is made with shell-lac and spirits without any other ingredients. It is usual to make the varnish thicker than is required for use, and to thin it down with spirit when being used. A tough polish is said to be produced from $1\frac{1}{2}$lb. of shell-lac, 4 oz. of seed-lac, 4 oz. of sandarac, and 2 oz. of mastic to the gallon of spirit; or 2lbs. of shell-lac and 4 oz. of thus to the gallon. A light-coloured varnish may be made with bleached or white lac; but this darkens by exposure to light.

The rubbers used for French polishing are sometimes made of small balls of wadding, such as is used for ladies' dresses, covered with linen rag. The rubber, which is about the size of a walnut, is placed on the open mouth of the bottle, which is then turned up, and the varnish thus collected is covered with a second rag, and moistened with one or two drops of linseed oil: the varnish gradually exudes according to the degree of pressure given to the ball, which is thrown away after being used 4 or 5 minutes, as it hardens from the accumulation of the varnish, and then scratches instead of polishing the work. This wasteful method is often superseded by the use of sponge, applied in the same manner as the wadding: this forms a durable rubber, but requires to be softened every time it is used. Small cloth or list rubbers are also used for laying on the first coat: the list should be torn off the cloth, which gives a softer edge than if cut; then wound up spirally to the diameter of 2 to 4 inches, and tied round tightly with string: these rubbers are covered with a cloth so as to be easily renewed; or the lower face of the rubber itself may be saturated with lacker, so as to soften that which may remain in the rubber from previous use, and the excess is squeezed out before commencing the polishing.

Mr. Holtzapffel remarks,[1] that the choice of rubber is not very material, provided it be moderately soft and contain a sufficient quantity of polish to allow of its being gradually supplied to the work as the polishing progresses; but the rubber must always be kept covered with a piece of soft rag moistened with oil, and renewed when it becomes so far clogged as to prevent the polish passing freely through it. Before the polishing, the work must be well smoothed with fine glass-paper, and the dust wiped away: the polishing is then commenced with free, continuous, uniform circular strokes with light pressure, and gradually extending over the whole surface, taking care that every portion receives an equal but moderate quantity of varnish, which is regulated by the degree of pressure on the rubber, and also by squeezing it between the fingers. The rubber must never be allowed to remain stationary on the work, or be lifted directly from it; when removed it should be slid off at the sides or ends of the work, or lifted off with a sweeping stroke so as to break contact gradually. The polishing is continued until the grain of the wood appears to be thoroughly filled up, and the surface exhibits a uniform appearance. It is then allowed to stand for an hour

(1) Mechanical Manipulation, vol. iii

or two to harden; after which it is smoothed down with very fine glass-paper. The polishing is then repeated; and, if necessary, again smoothed, and the polishing continued until the whole surface presents a smooth, uniform and tolerably bright appearance. Cloudy marks produced by the oil of the rubber will, however, still appear; these are removed with a clean rubber, covered with a clean soft linen rag and touched with a few drops of spirits of wine; with this the work must be rubbed with very light strokes, applied first with a circular motion, and when the surface is nearly dry, straight strokes are taken lengthways of the grain of the wood, and traversed entirely off the ends of the work: when the rubber and the work are quite dry, the polishing will be completed for that time. In the course of a few days, the polish having been partly absorbed by the wood, the surface should be again smoothed with very fine or nearly worn-out glass-paper, and the polishing repeated. The final body of polish must be as thin as possible, or the varnish will not be smooth and durable. See VARNISHES.

FRESCO PAINTING. An ancient and still esteemed mode of decorating buildings with paintings of a permanent kind, executed on the *fresco*, or *fresh* plaster of the wall. The nature of the work requires great rapidity and skill in the painter; all that is begun in the morning must be completed in the evening while the plaster is wet, as any subsequent retouching destroys the purity of the work. The general practice of this art relates to the following particulars:—1, the cartoon; 2, the preparation of the wall; 3, the painting; 4, the colours and implements used. Since the artist is unable, without injury to the general effect, to retouch a fresco painting, it is the more important that he should prepare beforehand a finished coloured sketch of the subject he intends to represent, and also a full-sized chalk drawing of the same. For this latter purpose he prepares a cartoon, by straining strong cloth on a frame, and then glueing layers of paper to the surface, which must be kept smooth and even, and finally prepared to receive the drawing by a preparation of size and alum. The drawing is made with charcoal, and when finished and fixed, an outline is traced from it on oiled paper. This is the working outline, a portion of which, corresponding with the quantity of fresco painting which can be executed at one time, is nailed to the wet wall, where the forms on the oiled paper are gone over with a sharp point so as to make a distinct indentation on the soft plaster beneath. Another way of producing the outline on the wall is, to place the tracing paper first, at the back of the cartoon, and prick the figures through, then to lay the pricked paper on the wall, and dust a black or red powder on it from a muslin bag. This produces a dotted outline on the plaster, and leaves the surface without indentation; but it injures the cartoon, and also gives less decided lines to work by. That both these methods were practised by the most celebrated painters, is evident from the pricked outline being visible in some of the works of Caracci and Raphael, and by the indented outline produced by tracing being likewise seen in some of the best Italian frescoes.

The preparation of the wall for fresco-painting is a matter of great importance. The chief thing to be dreaded is damp; therefore all old mortar is removed, and the solid wall laid bare, preparatory to a new coat of approved materials. This consists, in the first place, of lime and river sand, laid on roughly, and left to become perfectly dry and hard, before the smoother layers are added. The lime has to undergo careful preparation and seasoning before it is fit to be thus employed. The method of seasoning it, adopted at Munich, is as follows:—A pit is filled with clean burnt limestone, which is slaked, and then stirred continually till it is reduced to an impalpable consistence. The surface having settled to a level, clean river-sand is spread over it to the depth of a foot or more, so as to exclude the air, and, lastly, the whole is covered with earth. Thus it remains for two or three years, before it is used either for painting (lime being the white pigment) or for coating walls.

The final preparation of the wall consists in wetting it till the first rough coat will absorb no more water, then laying on a thin coat of plaster, and when this begins to set, adding a finer coat, containing more lime and less sand. This is done and the work smoothed with a wooden trowel; but only so much space is finished in this way, at one time, as can be painted on before it gets dry.

The wall thus prepared, the outline has to be obtained from the cartoon in one of the two ways already described. The colouring can be commenced as soon as the plaster is in that state in which it is damp enough to receive the impression of the finger, and not wet enough for the colours to run: if the drying goes on too rapidly, the surface of the plaster must be sprinkled from time to time with water. The colours, ground fine in water, are abundantly supplied to the artist in pots or basins, and several palettes are at hand to work from. Tiles, or other absorbent materials, are used to try the colours on, and to give the artist an idea of their effect when dried into the plaster. When the artist concludes his work for the day, he cuts away any portion of the prepared plaster which he has not used, taking care that the division is made in the folds of drapery, or in some other part of the painting where it will be unobserved: on commencing the next day's work he takes care to wet the edges of the finished part, and make them amalgamate as nicely as possible with the new plaster. The drying of the plaster is sometimes arrested by foreign artists by keeping wet linen stretched over the surface of the picture, and pressed to it by a cushion of waxed cloth: this enables them to finish in the morning what they were unable to complete overnight. Defects in a painting are sometimes remedied by cutting out a portion of old plaster, and painting that portion over again on new plaster. There are also various devices for heightening the effect of finished frescoes, but these are all objectionable, as impairing the durability of the work.

The colours used in this art consist chiefly of

earths and a few metallic oxides variously prepared. Animal or vegetable substances cannot be employed, because the lime would destroy them. Brushes of hogs' hair, and smaller pencils of otters' hair, are found to resist the action of the lime. Distilled water should be employed in all the operations connected with fresco-painting.

A new mode of fresco-painting, the invention of which is ascribed to a well-known German chemist, Obergrath von Fuchs, consists in the use of a solution of silex, instead of lime, and in the employment of a chemically prepared ground, which becomes exceedingly hard, and can be worked on repeatedly without detriment to the general effect.

Many valuable ancient paintings in fresco have been saved from destruction by ingenious modes of transferring them from badly constructed walls to canvas. An attempt of this kind was made at Brescia, in 1829, by Mr. Ludwig Gruner, and met with perfect success. The frescoes existed on the old walls of the convent of St. Eufemia. These were first thoroughly cleaned: a strong glue was then passed over the surface, to which a sheet of fine calico was affixed: other layers of glue and of calico were then added, and the whole so amalgamated by heat as to become of one substance with the plaster of the wall. The whole was then torn away, leaving the wall white, and the fresco adhering to the glue. To detach it, a still stronger glue, and one that resisted moisture, was applied to the back, and secured to the canvas. The subsequent application of tepid water gradually caused the calico and glue to loosen their hold, and leave the fresco in its new position.

Much interesting information on the subject of fresco painting may be gathered from the Appendices to the Reports of the Commissioners on the Fine Arts, 1842, 1843.

FRICTION is the resistance which opposes itself, in a greater or less degree, under all circumstances, to the motion of a body when in contact with another body. This resistance occurs, though to a less extent, when the surfaces are as well smoothed and polished as possible; and as it is not necessarily attended (at all events perceptibly) with any abrasion of those surfaces, it may probably have its origin in some modification of molecular adhesion.

The effects of this action have been studied under two conditions. The *friction of quiescence* is that which forms the resistance to the first motion of a body previously at rest on a surface. The *friction of motion* presents itself after movement has commenced, and acts continually to retard or check that movement.

The results of numerous experiments have established the following general laws of friction:—

1. That when no unguent or lubricating substance is interposed between the rubbing surfaces, the amount of friction, or the ratio of the resistance to sliding motion to that of the insistent pressure, is independent of the extent of the surfaces in contact and of the velocity of motion, and that it is determined solely by the nature and material of those surfaces and the force with which they are pressed together.

2. That when unguents or lubricating substances are used, the friction depends on the nature of the unguent, on its greater or less abundance, and on the proportion of insistent pressure to the extent of bearing surface.

These laws apply to both conditions of friction, but with more accuracy to the friction of motion than to the friction of quiescence.

The ratio which the resistance to sliding motion bears to the force pressing the surfaces together is called the *coefficient of friction*. Its value has been determined experimentally for almost all materials likely to be used as rubbing surfaces in practical works, and for all pressures varying between the lightest and that which produces abrasion of the substances in contact. The coefficient of the friction of quiescence is generally greater than that of the friction of motion, but as the smallest jar or shock is sufficient, during the application of a force tending to produce motion, to change the condition of rest to that of movement, the latter state may be assumed to exist in all cases of machinery. The condition of quiescence may be considered as occurring in statical problems of the stability of structures.

With respect to the materials forming rubbing surfaces, it has been found that the softer substances produce more proportionate friction than the harder, and, of course, in those the limits of abrasion are sooner reached than in the latter.

When unguents are used, the surfaces may be merely greasy, or, from the thickness of the lubricating matter, and the small insistent pressure, a complete film of this matter may be interposed between the rubbing parts. In the former instance, the resistance varies as little as possible from that due to the dry surfaces. In the latter, the surfaces in contact are practically not those of the hard materials, but two surfaces of hard material with one of the interposed grease. Hence, under these circumstances, the friction is found to depend more on the kind of unguent than on the nature of the bearing. Thus, surfaces of wood on wood, wood on metal, metal on wood, and metal on metal, when abundantly supplied with grease, have nearly all the same coefficient of friction, which varies between 0·07 and 0·08, when hog's lard or oil is used, and rises to 0·10 with tallow. With axle bearings of the usual materials, and greased in the usual way, the coefficient varies from 0·10 to 0·19 of the insistent pressure.

Much depends on the adaptation of unguents to the circumstances under which they are to be used. The softer greases, as oil, hog's lard, &c. diminish the resistance under small pressures more than under high pressures. The harder greases, as tallow, soft soap, and mixtures of grease and plumbago, produce less effect with small pressures than with large ones. The cause of this evidently exists in the different facilities with which the unguents can form a perfect separating film between the surfaces of contact, or are by an increase of pressure squeezed out so as to leave those surfaces in effect merely greasy. With each kind of lubricating matter there must evidently

exist a certain pressure per square inch of bearing surface, at which the unguent forms a perfect film between the rubbing parts. This is the state producing the minimum of resistance. An increase of pressure, by squeezing out this unguent, increases the coefficient of friction; and a diminution of pressure, by allowing the viscosity of the unguent itself to affect the result, may also add to the proportion of resistance.

The resistance produced by the viscosity or adhesiveness of the unguent itself is generally of too small magnitude to be taken into consideration in large machinery, but in watch and clock mechanism this resistance becomes of considerable importance.

Professor Moseley, of Cambridge, first made known a method of computing the effect of friction, which is of great practical importance. It may be briefly illustrated thus: If a body, M, Fig. 1008, be pressed upon a surface A B by any vertical force P, this force may be represented in direction and in amount by the vertical line M P, containing as many units in length as there are units of weight in the pressure P. Similarly, the friction

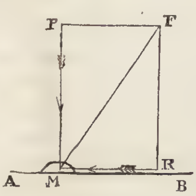


Fig. 1008.

due to this pressure, and which is dependent for its proportion to P on the nature of the surfaces in contact, may be conceived to act parallel with the surface A B in a direction opposite to that of any force tending to slide M along A B. Let this friction be represented in direction and amount by the line M R, which has the same proportion in length to M P that the resistance of friction has to the pressure P. Complete the parallelogram M P F R, which has these two lines for its adjacent sides, and draw its diagonal F M. Now the angle which F M makes with M P is determined by the proportion of M R to M P; that is, this angle is dependent on the friction between M and A B. In fact it is that angle the tangent of which is the coefficient of friction for these two surfaces. This angle F M P is called by Professor Moseley the *limiting angle of resistance*, and its property is, that if any oblique pressure be applied to M, this pressure, however great it may be, will not cause M to slip, unless it make with the perpendicular a greater angle than the limiting angle of resistance; and if it does thus make a greater angle than F M P, it will, however small it may be, cause M to slip on A B. This principle is of the highest value in mechanical problems, enabling questions of the stability of structures and of the useful effect of machines to be solved with facility and accuracy. If the line F M revolve about M P, it will describe an imaginary conical surface. This is the *cone of resistance*. Any pressure the direction of which lies within this cone will be resisted by M up to the point of crushing, and if its direction lie without this cone, it will not be resisted by M, but this body will slide on A B. [See BRIDGE, *Sec.* II.]

A table of the limiting angles of resistance accompanies many tables of the coefficients of friction. When not so given they may be found from any table of natural tangents, by seeking that angle whose tangent is equal to the coefficient of friction of the bodies in question.

From the brief illustration given above it is evident that when a single force, or the resultant of any number of forces, acting on any body, as M, is inclined exactly at the limiting angle of resistance for M and A B, then this force must be just on the point of causing the body to slide on A B. This, then, is the state bordering on motion, which enables us to determine the relation between the forces impressed on a body or system of bodies held by those forces in a state of rest, and allowing in this relation for the effects of friction. Hence, in all problems relating to the balance of forces in equilibrium, we know that the resultant, or joint effect of those forces, must be inclined to the surface on which motion is on the point of taking place, exactly at the limiting angle of resistance.

As an illustration of this application, let us suppose a lever A B, turning on an axis or pivot 3 inches in diameter, and distant 12 inches from one extremity of the bar and 8 inches from the other, to be so held in equilibrium by two forces, P and W, that P is just on the point of preponderating and overcoming W.

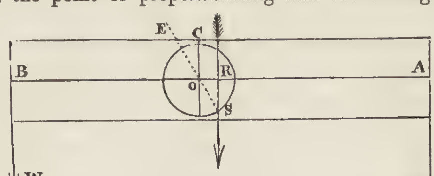


Fig. 1009.

It is required to determine the relation between these two forces in this state, taking friction into consideration. Now, since the axis is on the point of turning on its bearings, it is evident that the resultant of these two forces cannot pass through the centre of this axis, or it would produce no tendency to motion; but it must pass through such a point in the axis, that its direction, when prolonged, may make with the plane of junction between the axis and its bearing an angle equal to the limiting angle of resistance corresponding to the materials of which these parts are constructed. Suppose this angle to be 30°. Then, by construction, we proceed thus:—Draw the axis to a large scale, as in Fig. 1009; then, since both forces act vertically, their resultant must also act vertically, and it must evidently act on the side of the centre nearest to the preponderating force P. Draw the vertical radius C O; make the angle C O E equal to the limiting angle of resistance, and prolong E O to cut the circumference of the axis in a point S on the side of P. Through S draw a vertical R S; then the angle R S O equals the limiting angle of resistance. Then the point R, where the line S R cuts the axial line of the lever, is the point through which the resultant acts, and therefore from which the moments of these forces are to be measured. Now we see that if instead of the two forces P and W, a single force were acting parallel to the directions of P and W, that

is, vertically downwards, on the point R in the axis, this force would press the axis downward on the point of its bearing S, in a direction R S inclined to the surface of junction at S, at an angle R S O, equal to the limiting angle of resistance. This single force would therefore be on the point of moving the lever downward on the side of P, that is, it would be on the point of producing the same action as P and W. This single force, which could be substituted for any number of forces, and produce singly by itself the same effect which those forces were capable of producing altogether, is termed the resultant of those forces. If the forces P, W, instead of being parallel in direction, had been inclined to one another, an analogous, but more complicated process must have been adopted to ascertain that point of the circumference of the axis on which the whole resultant pressure might be conceived to act. When found, we know that at this point the direction of this resultant makes with the surface of bearing an angle equal to the limiting angle of resistance. Into this problem, however, it is not necessary to enter, as our only object is to explain the general application of the principle made known by Prof. Moseley, and to deduce at the same time the actual effect of friction in modifying the conditions of equilibrium.

Had this question been solved as a pure question, neglecting the effect of friction, the moments of P and W would have been measured from the centre O; and these forces, when in the state of equilibrium, would have had magnitudes inversely as the distances from O of their points of application; that is, P would have been 8 and W 12. But when friction is taken into account, the moments are measured from a point nearer to the preponderating force than the centre of motion. By actual construction the point R would be found to be 0·75 inch nearer to P than the centre O. That is, the distance P R is 0·75 inch less, and W R is 0·75 inch more, than the corresponding distances of P and W from O. Therefore these forces, which are in magnitude inversely as their distances from the point of application of their resultant, are found to be $P = 8·75$ and $W = 11·25$. But these forces are still only in equilibrium, though P is 0·75 more and W is 0·75 less than they were computed to be when the effect of friction was neglected.

From this we see that the effect of friction is to increase the amount of force necessary to be applied to produce any mechanical effect; or, which is the same thing, to diminish the useful effect W capable of being yielded by any applied force P. Had W been on the point of preponderating, the angle O S R would have been drawn on the other side of O S, and then we should have had the force W necessary to overcome P, increased by the amount due to the friction also to be overcome.

This effect of friction is quite general. The resistance due to this action may in all cases be regarded as so much additional power necessary to be expended to produce a given effect, or as so much less effect produced by the action of a given amount of power.

So far the statical effects of friction. In dynamical problems we have to remember that friction produces a constant retarding force, which, in order to the continuance of any motion, must be overcome through a space proportionate to the extent of such motion, by the expenditure of a corresponding additional quantity of working power. Now the amount of work necessary to be expended to overcome this resistance, is measured by the product of the actual magnitude of the resistance multiplied by the space through which it is overcome. It may be diminished, therefore, either by lessening the actual magnitude of the opposing resistance, or by diminishing the distance through which it has to be overcome. To accomplish the first, the parts should be made as light as possible consistent with strength, so as to diminish the weights on the bearing surfaces; and in cases where it is practicable, the driving power should be applied on the same side of the centre of motion as the resistance to be overcome. This important principle, also made known by Prof. Moseley, will be rendered clear by applying the conditions of the problem in Fig. 1009 to the case of a lever of the second order, instead of (as in the Figure) to a lever of the first order. The second means of diminishing the loss of work due to friction, by diminishing the space travelled over, leads to the axes or pivots of wheels and levers being made as small as possible: not to lessen thereby the amount of resistance, but to lessen the space through which the rubbing surface of the axis turns, and through which the resistance has therefore to be overcome. In both cases the judicious application of unguents is obviously an important element in the question.

In some cases the loss by friction is lessened by causing the bearing parts to rest, not on fixed surfaces, but on the circumferences of wheels or rollers free to turn on their axes. There is then no rubbing between the first bearing and the *friction wheel* or roller, the first simply rolling upon the second and turning it round with itself. The rubbing is confined to the pivots of these friction-wheels, and the spaces through which they move are obviously less than the spaces moved through by the original axis, in the same proportion that the circumference of the pivot of the friction-wheel is less than the circumference of the wheel itself. This method is applied in the apparatus well known as Atwood's Machine. It has also been applied to carriage axles, to railway wheels, to the pivots of large capstans, &c.

In large metal structures, as bridges, the expansion and contraction of the material must be allowed for by giving freedom of motion to the ends of the structure. But were this motion only allowed to take place by the sliding of the ends of the structure on the surfaces of its piers or supports, the enormous friction produced by such vast weights insistent on such rough surfaces, would practically render the ends almost rigid, and the force produced by changes of temperature would be exerted to crush or tear asunder the structure itself. To avoid this, it is usual to cause the ends to rest on balls or rollers, free to turn under the structure, thus substituting an entirely

rolling contact for one of rubbing surfaces. [See BRIDGE, *Secs.* V., VI.]

FRIT. See GLASS—ENAMEL.

FUEL. The chemical combination of two substances whereby heat and light are produced, constitutes the process of combustion in its extended sense. [See COMBUSTION.] The most common, as well as most ancient example of combustion, is where the oxygen of the atmosphere is made to combine with some substance easily procurable, such as wood, turf, pit-coal, &c. Such substances are known by the name of *fuel*, from the French *feu*, fire, which is derived from the Latin *focus*, a hearth or fireplace.[1]

The process of combustion is employed either as a source of *heat* or of *light*. The nature of the process and of the substances employed, together with the practical arrangements for carrying it on, render it impossible, or at least not desirable, to attain both objects at the same time; hence the production of heat and of light form distinct branches of industry. [See CANDLE—GAS LIGHTING—LAMP, &c. for the production of light; and for the production of heat, see the present article—COAL—CARBON—COKE—COMBUSTION—STOVE—WARMING, &c.]

Most of the operations in the Useful Arts require, directly or indirectly, the application of artificial heat, and the means of obtaining it are of first-rate importance in every manufacture. The political power of a country such as Great Britain is due, not to her army or her navy,—for these are defensive, not productive,—but to the great development of her manufactures; and this is in great measure dependent on an abundant supply of fuel easily procurable at a cheap rate.

WOOD. The carbonaceous parts of plants, whether found upon or under the surface of the earth, are peculiarly adapted for supplying an easily combustible fuel. This source is extensively distributed, and is in a constant state of reproduction. The trunk, roots, and larger branches of trees, form what is called *wood fuel*, or simply *wood*. In this variety of fuel there are three different substances to be considered: 1, the *woody fibre*, a compound of carbon, hydrogen, and oxygen, which constitutes the cells and vessels of the plant, and forms its chief bulk; 2, the *sap;* and 3, the *water*, existing in the vessels of the plant. Recently felled wood contains all three constituents: the first two are combustible, and produce heat; the third is converted into vapour, and expelled at the expense of the heat produced during the combustion of the other two. Woody fibre and water are common to all kinds of wood: the differences in woods are in the sap and in the density. In coniferous woods the sap is resinous; beech and birch contain extractive; oak contains tannin: the constituents of the sap, however, form a very small proportion of the whole bulk of the wood. The proportion of water is greatest at the time of the flowing of the sap, and least when the growth of vegetation is less rapid; hence wood should be felled in the winter, unless indeed it be cultivated more for the sake of the tannin in the bark than the wood, or the spot where it grows be inaccessible at that season. The amount of water differs in different species of wood, but in general in recently felled wood, from ¹th to $\frac{1}{2}$ of its weight is water, and in that which is commonly used for fuel, above $\frac{1}{3}$d: the quantity, however, greatly diminishes by exposing the wood to the air in a dry place. Thus, in 10 or 12 months, 100 lbs. of wood are reduced to 80 lbs. by the evaporation of the water, the value of the same as fuel being of course greatly increased.

Long immersion in water is injurious to wood in consequence of the loss of soluble matter dissolved out by the water, thereby diminishing its volume and heat-producing power: 1 cubic foot of wood may lose 1 lb. in weight by being floated from the forests down the streams, as is done for convenience of carriage in the Black Forest, Salzburg, &c.

When wood has been burnt, an incombustible residue or ash remains, consisting of earthy and alkaline salts, and forming from $\frac{1}{30}$th to $\frac{1}{70}$th of the wood.

The ultimate composition of different woods does not vary so much as might have been anticipated from their very different properties. Hydrogen and oxygen are contained in woody fibre in the same proportions as those in which they unite to form water, viz. 1 : 8; and this relative proportion is exceeded by the hydrogen in the different woods and in a variable manner.

PEAT. This substance is of great importance as fuel, and is becoming more so. In our Introductory Essay, p. lxxxiv., some details are given respecting the peat bogs of Ireland, and the important industrial applications of peat, which promise well for that fine but impoverished country. Small deposits of peat are found in almost every country, but districts of immense extent occur in Holland, North Germany, the Grand Duchy of Hesse, &c. In Germany, on the Rhine, the peat is cut by means of common spades into the shape of thick bricks, which are placed to dry on some kind of support. Care is taken to separate the peat of the upper part of the layer, which is young and fibrous, from the heavy and more abundant lower peat. In Holland the preparation of peat resembles the process of brick-making. The peat is scooped out with spades, as long as it is possible to do so, and when the spongy mass becomes too thin, an instrument is used consisting of a sharp iron ring fixed upon a handle, and perforated with small holes for supporting the bottom, which is formed of net or of cloth, so that on scooping up the muddy peat, the water drains off. The mud thus collected is converted into a homogeneous mass by treading with the feet, stirring about with rakes like mortar, and picking out the stones: it is then spread out evenly in layers, 1 foot thick, in large wooden boxes, such as are used for slaking lime, that the water may run off and the mass become dry. The boxes are previously strewed with stamped hay to prevent the peat from adhering to the box, and after some days, when the mass exhibits a certain consistence, a number of women strap flat boards like snow-shoes to their feet, and stamp it down until sufficiently compressed not

(1) Such derivatives are not uncommon in the French language, as *jeu* from *jocus*: *leu* or *lieu* from *locus*

to take an impression from a common tread: it is lastly stamped with beaters until the surface is uniform. The cake, now 8 or 9 inches thick, is divided by means of long laths into squares of about 4 inches, and these are gradually removed. The thickness of the cake is the length of the bricks, which are kept upright. In drying the cakes, the first one taken out is laid transversely upon the second; the third is laid upon the fourth, and so on; this order being reversed when the pieces are piled up.

In some places the peat mud is scooped out with buckets on to a dry place, and when the water has drained off, it is made into bricks with moulds. Too large an amount of water in the peat may completely destroy its value, and render it incapable of being piled. Its value increases in rapid proportion to its dryness, density, and firmness. If it possess these properties only in an inferior degree, it suffers by carriage and by keeping, the upper layers of the heap compressing and breaking the lower layers, which thus become valueless. The porosity and brittleness of peat prevent its application in all cases where fuel and matters to be heated are piled up to a height one above the other. Besides this, dense peat comprises in a like bulk much more combustible matter than porous peat. Hence the use of presses for condensing the peat. In one experiment, a brick weighing 8 lbs. lost 2·5 lbs. of water under the press. The longer peat is allowed to dry in appropriate sheds, the more it will improve as a heating agent. In some cases the quantity of ash yielded by peat is so large as to render the peat useless as fuel. This ash consists, *first*, of salts peculiar to vegetable matter, and which have not been dissolved out by the bog-water; and *secondly*, of the earthy matter collected during the deposition of the peat. Indeed, peat of various districts has been found to contain from 1 per cent. to one-third of its weight of ash. Carbonates of the alkalies are never found in it, but phosphates, sulphates, &c. In 100 parts of ash Einhof found 15·25 lime, 20·5 alumina, 5·5 oxide of iron, 41 silica, 15 phosphate of lime, 1·55 common salt and gypsum. Schübler found 34 per cent. of phosphates in the ash of peat from Schwenningen, thus making it valuable as a manure. The ash is otherwise injurious as causing dust and taking up much room, decreasing the quantity of combustible matter, and in smelting processes acting chemically.

Coal has already been treated of under that head: its value as a fuel will be more fully considered in the present article: Coke and Charcoal have been noticed in the article Carbon. In the Introductory Essay, p. lxxxiii., that description of fuel made from a mixture of coal-dust and pitch, and known as Patent Fuel, was slightly noticed. The advantages of this kind of fuel are economy of money and of space:[1] for waste and refuse coal is used, such as from its pulverulent state is unfit for the ordinary purposes of combustion. This invention, although new to us, is an ancient one, for the Chinese have been accustomed for ages to mix their powdered fuel with a compost of soft clay just sufficient to make it cohere; cow-dung or other refuse vegetable matter is also used: balls are then formed of this mixture, which are dried in the sun or open air. This method is not adopted on account of the scarcity of fuel, for coal is abundant in China; but the Chinese, unlike the English, know how to take care of it. These fire-balls during combustion give out very little smoke: they are largely manufactured in the coal districts, and are distributed by canal over a large portion of the empire. Powdered fuel mixed with clay is also sold in some parts of continental Europe as *combustible bricks*. Peat has also been converted into patent fuel: by Hill's process the peat is distilled dry, and the pyroligneous spirit and tar collected: the tar is converted into pitch, which is mixed while hot with the peat charcoal. Wylam's method of making patent fuel involves several distinct branches: 1st, the separation of coal tar by distillation into naphtha, dead oil, and pitch; the pitch is mixed with small coal and moulded into bricks, as will be described presently. 2. The naphtha is rectified, and sold as such. 3. The dead oil is converted into ivory black, and is also used for other purposes. 4. The pitch, having become hard, is ground under edge stones, and mixed with small coal in the proportion of 1 to 4. This mixture of coal and pitch is carried up into a large hopper, from which it gradually passes into the receivers, m m, Fig. 1010, at the bottom of which a pair of plain

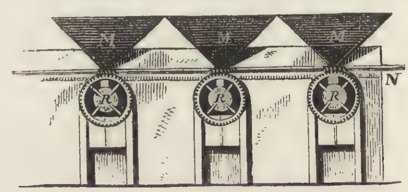


Fig. 1010

Fig. 1011.

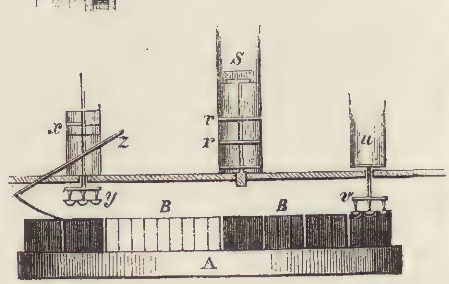


Fig. 1012.

rollers o, Fig. 1011, are kept in motion by the shaft n, Fig. 1010; and in this way a regular supply is

(1) Its importance in this respect may be judged of from the fact that the Mammoth Steam-packet, of 1,000 horse-power, requires for one journey 81,884 cubic feet, or 2,240 tons of coal.

thrown into the retort R. An Archimedean screw Q, Fig. 1011, inside the retort, is also made to revolve by means of the shaft N. The retort is kept at a dull red heat by the hot air of the flue T, and the fuel passes through the whole length of the retort, which is about 15 feet, in about 3 minutes. The mass of coal and pitch is discharged at the opposite end of the retort in a pasty state, and carried by an endless chain into the receiver s, Fig. 1012, where it is kept in motion by the arms *r r*, so as to prevent it from hardening into lumps. From this cylinder or receiver it runs into large moulds, where it is subjected to a heavy pressure in the following manner: A is a movable oval table upon which the moulds B B are fixed; s the vessel which receives the fuel paste; *u* and *x*, two cylinders similar to the cylinders of a steam-engine, but worked by water; *v y*, the pistons, to which two rams are attached, each having 6 arms fitting accurately into the moulds B B; and *z* is a lever, worked by means of the piston *y*. The moulds are filled from the vessel s as the table is made to revolve by the movement of the lever *z*. As the moulds approach the cylinder *u* the piston descends and compresses the fuel with enormous force; and after the piston rises, another set of moulds take their places, while the piston *y* of the cylinder *x*, having descended at the other end of the table, the six bricks are forced out of the moulds, and are received below ready to be stamped with the maker's name. The composition of these bricks appears to be—

Coke	Carbon	61·67
	Ashes	7·08
Gaseous matter		31·25
		100·00[1]

The relative values of fuel is a very important inquiry. Different kinds of fuel produce very different amounts of heat, and various methods have been adopted for ascertaining their maximum effect. To find the theoretical effect of any fuel, we must know the *quantity* of heat which a certain amount of such fuel is capable of producing, and the *time* required for effecting that object. These two points furnish the *heating power*, on which its value as fuel (in conjunction, of course, with its market price) depends. But as heat cannot be weighed or measured, it is impossible to ascertain the *quantity* of heat produced by a body during combustion; but it is not difficult to ascertain the effect of one kind of fuel compared with another kind; how much one kind exceeds or falls short of the other. This gives a relative value to the fuels, although the actual quantity of heat produced by each is altogether unknown. One of the methods of making this comparison is to cause the whole quantity of heat evolved by the fuel under examination to act upon a third body, which producing different effects under the action of different kinds of fuel, thus affords a standard of comparison. Lavoisier and Laplace caused the heat of their calorimeter to act upon ice, and they measured the heat by the quantity of ice melted. Rumford used water instead of ice, and measured the quantity of heat by the increase of temperature in a given quantity of water. Both methods are similar, if we bear in mind that the same quantity of heat which will melt 1lb. of ice at the zero of the centigrade thermometer, is just sufficient to raise the temperature of as much water 79° Cent., or, what is the same thing, to raise 0·79lb. of water 100° Cent. When it is also remembered that an equal weight of aqueous vapour, whatever its temperature and tension, is always formed from one and the same amount of heat, and, consequently, always contains the same quantity, and that the quantity of heat which water at 100° Cent. absorbs or renders latent in order to become vapour, would be 5·5 times sufficient to heat the same weight of water from 0° to 100° Cent.: hence, it is easy to calculate how much water would be converted into vapour by the heat required to melt 1 lb. of ice: it is found to be the 5·5th part of the same lb., or in other words, it is capable of converting into vapour 0·154 lb. of water.

Despretz and Welter found that those quantities of a combustible body which require equal amounts of oxygen for combustion, evolve also equal quantities of heat, and this was made the measure of the heating power. [See COMBUSTION.] Indeed, considering that the heat evolved must bear some relation to the mass of the body burned, so the oxygen may also be regarded as the combustible as much as the fuel with which it combines. When, therefore, oxygen burns by means of carbon, wood, hydrogen, &c., the heat evolved must increase with the quantity of oxygen consumed. On this supposition Berthier founded a practical process for detecting by one experiment the quantity of oxygen required for combustion, and thus the heating power of the combustible. This process is, to heat to redness a weighed quantity of the combustible with a large excess of pure litharge, until the combustible is completely consumed by the oxygen of the oxide of lead, as it would be by the oxygen of the air. Every equivalent of oxygen thus consumed leaves an equivalent of reduced metallic lead, and it is only necessary to weigh this reduced lead in order to discover the amount of oxygen consumed, and consequently the heating power, the object being merely a comparison of the relative powers of the different kinds of fuel.

The lighter kinds of woods contain more hydrogen than the heavier, so that the first stage of their combustion with flame is increased at the expense of the second—viz. the incandescence of the charcoal; hence they burn with greater facility, and evolve their heat in a shorter time than the hard woods; hence, also, lighter woods are more combustible than harder, and give out more heat, inasmuch as 1 equivalent of hydrogen requires 3 times as much oxygen (evolving 3 times as much heat) as 1 equivalent of carbon.

The state of division of a fuel is a point of im-

(1) Appendix to Knapp's Technology, by Dr. E. Ronalds and Dr. T. Richardson. Vol. I. 1848. The work itself has also furnished us with considerable information in the preparation of this article.

portance. A cwt. of wood in the state of shavings will expose a much greater amount of surface to the air than when in the form of a log. Numerous portions of wood will be burning at one time in the former case, while in the latter the surface is only, or chiefly acted on; and while the log will maintain a moderate temperature for hours, the shavings may produce a red heat in the sides of the furnace in a few minutes. But as the amount of combustion, or quantity of fuel, consumed in a given time, increases by a state of division, so if this state is increased beyond a certain limit, it acts in an opposite manner, and destroys combustion altogether. Thus saw-dust, charcoal, or peat in powder, crushed coal, &c., cease to be combustible under ordinary circumstances, because the small particles lie so close together that the air necessary for combustion cannot penetrate. If coal be of a caking quality, its dust can be converted into compact coke; but fuel which falls to pieces in the fire without caking, has many of the objections of powdered fuel. The pulverulent waste from peat, wood charcoal, and pit-coal may now be converted into patent fuel, and on the continent small fuel is often used in glass-works and for boiler fires, the grate-bars having been previously covered with lumps of sandstone, limestone, &c., to prevent the powder falling through the grate, and to distribute the supply of air through the fuel. An ingenious application of clinkers to the same purpose is described in the article COPPER, p. 428.

The quantity of heat obtained from fuel in the useful arts and manufactures falls very far short of the theoretical value. A considerable portion of the heat is either not evolved, or is lost without any useful effect. The application of fuel to practical purposes is called *heating* or *warming*, [see WARMING,] and its object is to evolve the heat from the fuel as completely as possible, and to apply it without loss to the purpose it is intended to serve, as in the processes of boiling, roasting, smelting and forging operations, the warming of dwellings, &c.

Some valuable information respecting fuel, especially as regards the coals of our own country, is contained in the reports "on the coals suited to the steam navy, by Sir H. De la Beche and Dr. Lyon Playfair."[1] This inquiry was undertaken at the public cost, on the establishment of a steam navy, and the reports are published under the authority of the Government. We propose to lay before our readers as full an abstract of these valuable documents as our limits will allow.

Considering the purposes to which the coal was to be applied, the chief test of the value of any particular coal was its *evaporative power*, or power of converting water into steam. Thus, if a given weight of coal in a certain time converted a larger portion of water into steam than a similar weight of another coal, the evaporative power of the first would be greater than that of the second. It is shown, however, by this inquiry, that the true practical value of coals for steam purposes depends upon a combination of qualities which could only be elicited by careful and continued experiment. Their qualities, so far as regards steam-ships of war, are stated as follows:—1. The fuel should burn with a quick action, so that steam may be raised in a short period. 2. It should possess high evaporative power; that is, be capable of converting much water into steam with a small consumption of coal. 3. It should not be bituminous, lest so much smoke be generated as to betray the position of ships of war when it is desirable that this should be concealed. 4. It should possess considerable cohesion of its particles, so that it may not be broken into too small fragments by the constant attrition which it may experience in the vessel. 5. It should combine considerable density with such mechanical structure that it may easily be stowed away in small space; a condition which, in coals of equal evaporative values, often involves a difference of more than 20 per cent. 6. It should be free from any considerable quantity of sulphur, and should not progressively decay, otherwise, in either case, it is liable to spontaneous combustion.

The above conditions are never united in one coal. Anthracite, for example, has very high evaporative power, but not being easily ignited, is not suited for quick action. It has great cohesion in its particles, and is not easily broken up by attrition, but it is not a caking coal, and, therefore, would not cohere in the furnace when the ship rolled in a gale of wind. It emits no smoke, but from the intensity of its combustion, causes the iron of the grate-bars and boilers to oxidize, or waste away, rapidly. Thus, with many advantages, anthracite has several defects which under ordinary circumstances preclude its use. It was thought that the above conditions might be united in some of the fuels prepared from coals possessing the various qualities, after the manner of patent fuels, and with this object experiments were directed to be made with the view of preparing such a fuel. Hence, in order to obtain a knowledge of the coals of different districts, Wales was first selected for examination, as producing coals of all kinds, varying from bituminous to anthracite. The result of these experiments was not favourable. The cementing tar, though partially carbonized by the heat of the coking-ovens in which the prepared fuels are heated, was so much more combustible than the dense and difficultly burning anthracite, that the latter remained after the combustion of the former, and either accumulated on the bars in the state of powder, obstructing the draught, or falling through the grate escaped combustion. If thrown again on the fire, it choked the air-way and impeded the proper action of the fuel. The evaporative power of the fuels thus prepared was found to increase according as the proportion of fixed carbon was augmented; but this would appear to arise from the fuel then assuming more of the characters of the anthracite or coke from which it was made. The results of the experiments indicated the necessity of keeping a uniform character in the fuel manufactured.

In the selection of the coals for trial careful

(1) Date of the first Report, 1848; of the second, 1849.

inquiries was made at the different ports in the neighbourhood of the coal-fields as to the kind of coal exported for steam purposes. Information from steam-ship companies, in the habit of using the coals of that district, was collected, and the local character of the fuel was ascertained. Circulars were then forwarded to the owners of such coals, explaining the object of the inquiry, and requesting them to furnish 2 tons for experiment. In most instances the coal was sent, but in a few cases the owners declined to do so; and as it was contrary to the spirit of the inquiry to report on the merits of coals contrary to the wishes of the owners, no coal was examined except such as was delivered free of expense to the commissioners, under the certificate of the owner or his agent.[1]

The method of testing the cohesive power of the coals, was by means of a wooden cylinder, 3 feet in diameter, and about 4 feet long, each end with a bearing or gudgeon attached to it; in the interior were fixed 3 shelves, each 6 inches wide, tending to the axis, for the purpose of forming a lodgment for the coals, and of carrying them up towards the top of the cylinder during its revolution, thus ensuring a certain amount of fall. The coals being put in at a door at one end, the cylinder was supported by a tressle at one end, the other gudgeon resting on a block let into the wall, and motion was communicated by a band passing round its circumference. The coals to be tested were first broken to the size employed in the experiments on their evaporating power, then thrown on a sieve, the meshes of which were 1 inch square. Of the coals left on the sieve 100 lbs. were put into the cylinder, which was then turned a certain number of times. The coals were again sifted on the same sieve, and the weight remaining gave the per centage of large coals found in the tables. These values are the mean of 2 trials with each coal, with 50 revolutions.

Each coal was subjected to experiment for 3 successive days, the draught being differently arranged for each day, either in the proportions of 4 : 5 : 8 or 1 : 2 : 4. In this way it was easy to ascertain when the gases escaping from the coals were most economically consumed. The coals most liable to be influenced by the different adjustments for the admission of air, are those which from their bituminous characters are most apt to generate a large quantity of gaseous products on the first application of heat, such as the coals from the Northumberland, Durham, and Lancashire coal-fields; and it was, therefore, found that the experiments made with them under different areas for the admission of air, vary much more considerably than the less bituminous coals of the South Wales coal-field. It was soon found necessary in the highly gas-giving coals, such as the Cannel coal of Wigan, to allow air to enter behind the fire-bridge, so as to complete the combustion of the escaping gases.

The experiments were conducted at the College for Civil Engineers, at Putney, by Professor John Wilson and Mr. J. Arthur Phillips, assisted by some other gentlemen of scientific attainments. The boiler-house is described as a rectangular building, 35 feet in length, and 16 feet 6 inches in breadth. The brickwork of the boiler is built against one of the end walls; its width being 7 feet 8 inches, and length 15 feet; the side is separated from one side wall by an interval of 18 inches, for the purpose of preventing loss of heat from the boilers by conduction through the external wall; by this means, also, ready access is gained to the base of the chimney D, Fig. 1013. The tanks E F for supplying the boiler with water, are made of wrought-iron plates, riveted together and placed outside the roof, the cast-iron pipe which supplies them with water being brought up inside the building to defend it from frost. The extremity of the pipe is furnished with the means of directing the flow of water into either tank at pleasure, and a two-way cock, *b*, connected with the tanks, directs in a similar way the supply from them to the boiler. A cock on the feed-pipe a short distance below this regulates the quantity of water admitted to the boiler. The boiler is cylindrical in form, 12 feet in length and 4 feet in diameter, with flat ends, and an internal flue 2 feet 6 inches in diameter, in one end of which the grate is placed. This is the usual form of *Cornish boilers*. The flues are on the *split* or *bridle* draught plan, in which the column of heated air, after leaving the fire, passes through the internal flue to the rear of the boiler, where it divides, returning along the outside of the boiler on both sides to the front; the two branches, which are each 2 feet 6 inches deep, then turn down at right angles to their former course, and uniting under the boiler in the bottom flue, which is 2 feet 6 inches wide, traverse its whole length again and finally enter the base of the chimney, after exposing, during a course of about 36 feet, an area of 197·6 square feet of boiler surface to the heating action. In the horizontal part of the flue at K, just before entering the chimney, a damper is placed sliding vertically in a cast-iron frame, which is worked by means of a rod passing through a stuffing-box and attached to a cord K′ carried over two pullies, and furnished with a balance weight, so that a person standing near the fire-door can easily regulate the amount of draught. The internal dimensions of the chimney, 182¼ square inches; the whole height, 35 feet 6 inches. Apertures were made in the chimney about 6 feet from its base, for the purpose of making observations on the temperatures of the currents, and of obtaining samples of the gases for analysis. Openings were also made at the end of each of the side flues, and at the base of the chimney, for the purpose of drawing out the soot at the end of each set of experiments. The floor of the flues is laid in fire-tiles, to facilitate its removal. When the furnace is in action, the apertures at the end are closed, and loss of heat prevented by means of stone doors 4 inches thick; then an interval for air about 1 inch thick; and, finally, cast-iron hanging doors lined with fire-clay. The fire-grate is 2 feet 6

(1) In the article COAL, p. 384, the elementary analysis and economic value of some of the coals examined are exhibited in a tabular form. See also the Table at page 722.

inches wide and 2 feet long, thus giving an area of 5 square feet of grate surface; the bars are $\frac{3}{4}$ inch in thickness, with $\frac{1}{2}$ inch spaces between them. In the front end of the grate, near the fire-door, is an iron plate (named a *dead-plate*), for the purpose of gradually heating the coals; it is 10 inches wide, and slopes down to the grate; beside this is another plate 8 inches wide, sloping upwards to the fire-door, contracting it in its width to 15 inches, which is the width of the aperture for the introduction of fuel. The fire-doors used for closing the entrances to the grate and ash-pit, were on Mr. Sylvester's plan, and well adapted for preventing the loss of heat, regulating the direct supply of air to the fire, and the convenient application of fuel. In this arrangement, *c d*, Fig. 1014, is a large cast-iron plate let into the brick-work, and having 4 projecting brackets, *e e*, *f f*, in which are secured the ends of stout cylindrical bars which are to carry the doors. The apertures to the grate and ash-pit are surrounded with an iron rim or edge, about $\frac{1}{2}$ inch wide, the lower part being continued backward along the plate, forming a kind of guide, *g h*. The fire-door, which exactly resembles the ash-pit door, consists of a rectangular cast-iron box, having its edge ground so as to fit accurately the iron rim before described, and the interior is filled

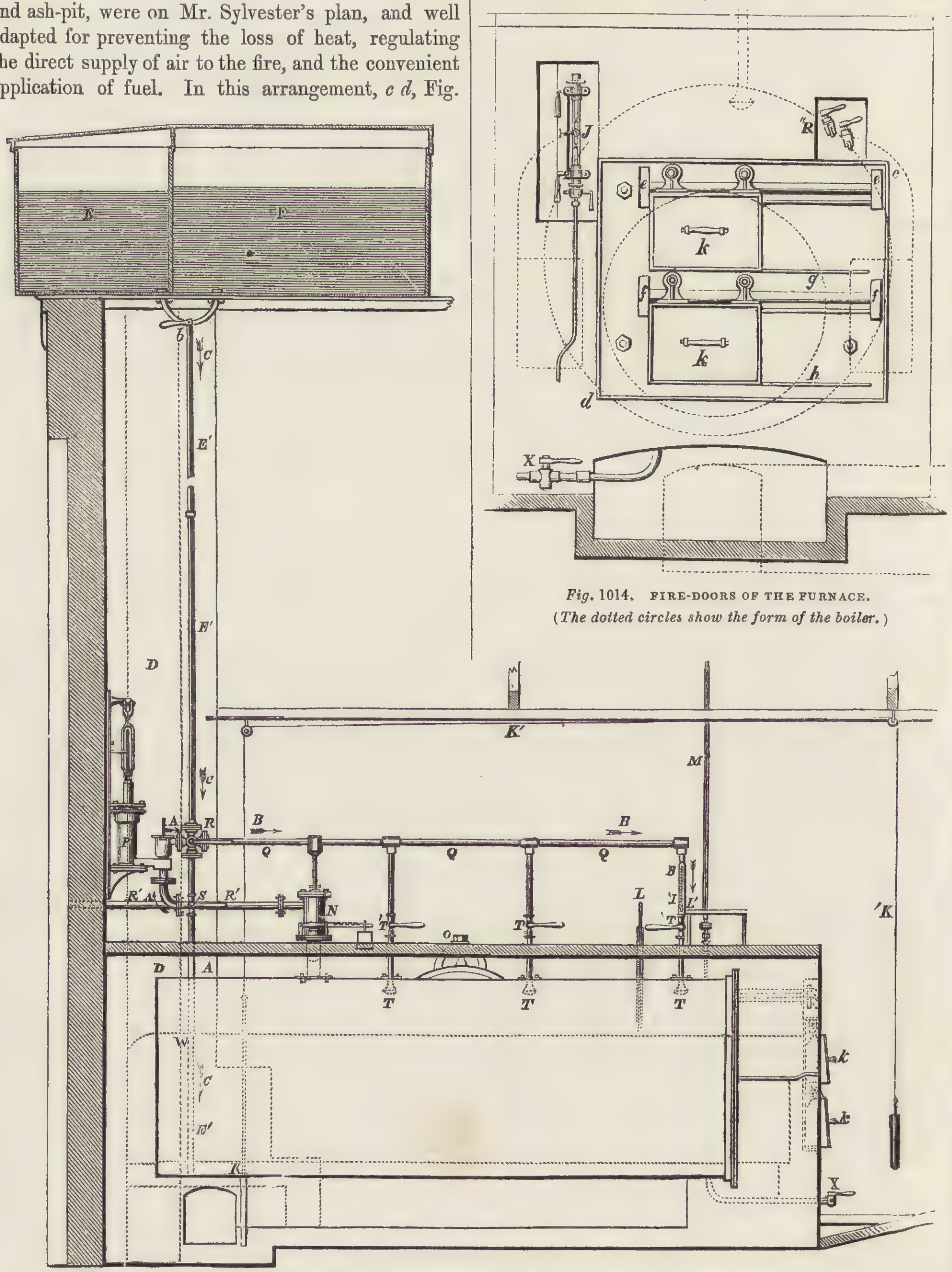


Fig. 1014. FIRE-DOORS OF THE FURNACE.
(*The dotted circles show the form of the boiler.*)

Fig. 1013. THE BOILER AND ITS ASSOCIATED APPARATUS USED IN THE EXPERIMENTS ON STEAM-COAL.

with, first, a layer of fire-brick, then a space for air, and then another thickness of fire-brick, which effectually prevents loss of heat. The top of the door has projecting ledges, forming the cheeks for two friction wheels, *l l*, which run on the cylindrical bar already mentioned, so that when the door is drawn sideways by means of the handle K at its back, the wheels roll along the bar, the lower part of the door sliding at the same time closely along the ledge or guide *g*. The two sides of the aperture are sloped gradually, so as with the lower edge to project more at bottom than at the top; this causes the weight of the door to act in keeping the surfaces in contact. The boiler has three safety valves, one of which is loaded directly, and has an area of 5.4 square inches, and two smaller steelyard valves, each having an area of 2.07 square inches. In the experiments, the boiler was worked the first two days with a pressure of 1lb. per square inch, and generally on the third day with a pressure of 3 lbs. on the inch. The thickness of brickwork at the crown of the boiler is 4½ inches, and the valves were brought up on a level with it and then paved, thus forming a large platform, and affording convenient access to the different thermometers and apparatus. Openings were made into the side flues in about the middle of their length, in which were fixed iron tubes closed at the lower ends, and containing oil in which the thermometers were placed for giving the temperatures; a similar tube was inserted at K in the base of the chimney, and another in the boiler at L, to give the initial temperature of the water in it.

The method of conducting the experiments is now to be described. Supposing the water in the boiler to be cold, and to stand about 1 inch below the normal level, the fire was lighted and the steam got up in the afternoon of the day preceding the commencement of the experiments. The fire was then allowed to burn out, when the fire and ash-pit doors and the damper were all closed. The next morning the first thing done was to open the safety valve to equalize the external and internal pressures, and then sufficient water was let down from the tanks to raise that in the boiler to the normal level. The depth of the water in the tanks was then gauged, and the first observation of its temperature made. The ashes, cinders and soot, were next cleared out, and after noting the temperature of the water in the boiler, the fire was lighted with a weighed portion of wood, and the exact time was then observed. The coals were then gradually added till the fire was of the proper size and form. The form of fire was slightly varied according to the kind of coal employed, the object being to burn the coal to the best advantage with as little smoke as possible at the chimney. The observations of the temperatures of the two side and escape flues, and of the water in the tanks, then succeeded each other at regular intervals of about one hour each. When the steam raised the safety valve the time was observed and entered under the heading *steam-up*. The damper was adjusted as soon as the fire was sufficiently established, and was not disturbed during the day, except under peculiar circumstances. When, by evaporation, the water had sunk about 1 inch below the normal level, the deficiency was supplied from the tanks above; or, by the plan afterwards adopted, the water was allowed to flow in continuously, so as to maintain the water in the boiler at a constant level. The fire was supplied with coals in pieces not exceeding 1lb. weight each, and not more than one or two shovels-full at a time, and were usually spread evenly over the fire; but in the case of anthracite, it was found that the sudden application of heat caused the pieces to split and fall through the bars. They were, therefore, gradually heated on the dead plate before being put on. With the bituminous coals a preparatory process of partial coking on the dead plate prevented them from coking in the fire (which would have impeded the passage of air through the grate), besides giving better opportunity for burning the smoke and gases by passing them over a large surface of ignited fuel. The duration of the experiment was reckoned from the time the steam was up to about that of the last application of fuel, after which the fire was allowed gradually to burn out, when the damper, and furnace and ash-pit doors were closed. During the day, ashes were thrown up in small quantities from time to time, when the fire was burning clear and well. The weight of coals consumed was then ascertained, by deducting the weight left from the gross weight provided for the day's trial, when the experiment terminated. The next morning, when the level of the water in the boiler was adjusted by turning down a supply from the tanks, their depth was gauged, and the quantity evaporated the previous day was thus ascertained. The coke and cinders were then removed, the clinkers, if any, were separated, and the weight of each taken. The soot was cleared out at the end of the last day's experiment, and the total weight recorded, which, divided by the number of trials, gave the average weight. Samples of the ashes, cinders and soot, were then put aside in bottles for the purpose of ascertaining the per centage of combustible matter present in the residue. The barometer was observed at about 11 o'clock in the day, being generally about 2 hours after the steam was up.

The method of estimating the quantity of combustible matter in the residue, was to heat the powdered substance in a stream of oxygen gas, by which the organic matter was dissipated chiefly as carbonic acid and water, and to estimate the loss as combustible matter.

Some difficulty was found in obtaining the mean temperature of the water in the boiler at the beginning and end of an experiment, arising from the normal level being established by letting down water to the bottom of the boiler by means of the pipe E′ E′ E′, and cold water being denser than hot, the cold water remained at the lower part of the boiler without mixing with that already contained in it, the two temperatures often varying as much as 70°, which would make a considerable difference between the real and apparent weight of the water contained

TABLE OF THE ECONOMIC VALUE OF COALS USED IN THE INQUIRY.

Names of Coals employed in the Experiments.	Economic evaporating power, or number of lbs of water evaporated from 212° by 1 lb. of coal.	Weight of 1 cubic foot of the coal as used for fuel. lbs.	Weight of 1 cubic foot, as calculated from the density. lbs.	Ratio of B to C, or of the economical to the theoretical weight.	Difference per cent. between theoretical and economical weights.	Space occupied by 1 ton in cubic feet (economic weight).	Results of experiments on cohesive power of coals: percentage of large coals.	Evaporating power of the coal after deducting for the combustible matter in the residue.	Weight of water evaporated from 212° by 1 cubic foot of coal.	Rate of evaporation, or number of lbs. of water evaporated per hour. Mean.
Welsh Coals.—	A	B	C	D	E	F	G	H	I	
Graigola	9·35	60·166	81·107	·742	34·8	37·23	49·3	9·66	581·20	441·48
Anthracite (Jones & Co.) .	9·46	58·25	85·786	·679	47·26	38·45	68·5	9·7	565·02	409·37
Old Castle Fiery Vein .	8·94	50·916	80·42	·633	57·946	43·99	57·7	. .	455·18	464·30
Ward's Fiery Vein . .	9·40	57·433	83·85	·685	46·0	39·0	46·5	10·6	608·78	529·90
Binea	9·94	57·08	81·357	·702	42·53	39·24	51·2	10·3	587·92	486·95
Llangennech	8·86	56·93	81·85	·695	43·76	39·34	53·5	9·2	523·75	373·22
Pentrepoth	8·72	57·72	81·73	·705	40·17	38·80	46·5	8·98	518·32	381·50
Pentrefelin	6·36	66·166	84·726	·781	28·051	33·85	52·7	7·4	489·62	247·24
Duffryn	10·14	53·22	82·72	·643	55·43	42·09	56·2	11·80	540·12	409·32
Mynydd Newydd . . .	9·52	56·33	81·73	·689	45·09	39·76	53·7	10·59	536·26	470·69
Three-quarter Rock Vein	8·84	56·388	83·60	·674	48·26	39·72	52·7	. .	498·46	486·86
Cwm Frood Rock Vein .	8·70	55·277	78·299	·706	41·648	40·52	72·5	9·35	480·90	379·80
Cwm Nanty-gros . . .	8·42	56·0	79·859	·701	42·60	40·0	55·7	8·82	471·52	404·16
Resolven	9·53	58·66	82·354	·712	40·39	38·19	35·0	10·44	559·02	390·25
Pontypool	7·47	55·7	82·35	·676	47·845	40·216	57·5	8·04	416·07	250·40
Bedwas	9·79	50·5	82·6	·611	63·565	44·32	54·0	9·99	494·39	476·96
Ebbw Vale	10·21	53·3	78·81	·676	45·98	42·26	45 0	10·64	544·19	460·22
Porth-mawr	7·53	53·3	86·722	·614	62·7	42·02	62·0	7·75	401·34	347·44
Coleshill	8·0	53·0	80·483	·658	51·85	42·26	62·0	8·34	424·0	406·41
Scotch Coals.—										
Dalkeath Jewel Seam . .	7·08	49·8	79·672	·625	59·984	44·98	85·7	7·10	352·58	355·18
,, Coronation Seam	7·71	51·66	78·611	·657	52·17	43·36	88·2	7·86	398·29	370·08
Wallsend Elgin . . .	8·46	54·6	78·611	·694	43·78	41·02	64·0	8·67	460·82	435·77
Fordel Splint	7·56	55·0	77·611	·699	42·92	40·72	63·0	7·69	415·80	464·98
Grangemouth	7·40	54·25	80·48	·674	48·35	40·13	69·7	7·91	401·45	380·40
English Coals.—										
Broomhill	7·3	52·5	77·988	·673	48·55	42·67	65·7	7·66	383·25	397·78
Lydney (forest of Dean) .	8·52	54·444	80·046	·68	47·02	41·14	55·0	8·98	463·86	487·19
Slievardagh Irish Anthracite	9·85	62·8	99·57	·630	58·55	35·66	74·0	10·49	618·58	473·18
Patent Coals.—										
Wylam's Patent Fuel . .	8·92	65·08	68·629	·948	5·45	34·41	..	9 74	580·51	418·89
Bell's ,, ,, . .	8·53	65·3	71·124	·918	8·91	34·30	..	8·65	557·0	549·11
Warlick's ,, ,, . .	10·36	69·05	72·248	·955	4·49	32·44	..	10·60	715·35	457·84

in the boiler; and as this was one of the elements employed in calculating the evaporative value of the coals experimented on, it was thought important to be able to find the true mean temperature, which was done by means of a mixing apparatus consisting of a force pump P, by means of which water can be drawn from the bottom of the boiler, and passing in the direction of the arrows *a a a*, *b b b*, be distributed on the top by means of the perforated extremities of the tubes T T T. In another position of the three and four-way cocks R and S, the water passes directly from the tanks to the bottom of the boiler; while by a third modification in the position of the plugs of the cocks R and S, the water can be made to flow directly on the top of the boiler from the tanks E F, as shown by the arrows *c*, *b*. This mixing apparatus was used at the beginning and end of each experiment in the following manner:—Suppose an experiment to have been made the previous day, the first thing done in the morning was to turn the cocks R and S in a proper position, and then, by means of the pump P, force water from the bottom of the boiler on the top at T T T. This generally lasted ten minutes: when the cocks R and S being turned in another position, the normal level was restored by letting down water from the tanks in the direction of the arrows *c b*, when the cold water flowing from the apertures T, being denser than that contained in the boiler, falls to the bottom, and in doing so abstracts heat from the warm water through which it passes, until the equili-

brium is restored; the temperature is then read off by means of the thermometer, and the cocks R and S are turned so as to allow water to flow directly to the bottom of the boiler in the direction *c*, in which position they remained during the whole of the experiment. The cocks T′ T′ T′ were shut to prevent the condensation of steam in the mixing apparatus, and also to cut off all communication with the boiler. In this way the temperature of the water in the boiler was made uniform, a difference of 2° being rarely observed between the thermometer L, and a thermometer placed in a stream of water allowed to flow from the cock X.[1] These operations were repeated every morning during the progress of the experiments, as also on that of the fourth day, when the series of experiments was completed. This last temperature is used in the calculations of the work done on the third day, whilst in the other cases the final temperature of one day is evidently the initial temperature of the succeeding.

Every sample of coal submitted to examination was accompanied by a certificate from the owner or his agent, and in the report a variety of particulars respecting the mine, the geological position of the coal, the method of working, the nearest port, the extent of trade, the physical character of the coal, &c.: and the results of the above experiments are added in a tabulated form. The following particulars respecting the Duffryn coal will show the mode of entry for all the coals examined :—

Duffryn Coal.

"I hereby certify that the casks of coal marked as in the margin of this certificate, contain a fair sample of the Duffryn steam coals, which were mined specially for the service of the 'Admiralty coals investigation.'—R. K. Jones, *Agent*."

The Duffryn steam coal is called the four-feet vein, and is obtained in the valley of Aberdare near Merthyr, in the county of Glamorgan. The depth of the pit is 288 feet, and the thickness of the vein is generally about 6 feet. It is worked in the form of stall and heading: the small and refuse is cast back or gobbed in the stalls and waste: the large coal is filled into wagons containing about a ton each, and conveyed from the stalls or heading to the top of the pit. The overlying stratum is strong clod or rock, and the subjacent stratum is strong fire-clay and rock. The dip of the vein is 1 in 9, or 4 inches in the yard, and crops towards the north. It is described as a free-burning coal, and its principal markets are London, Liverpool, Southampton, Dublin, and Plymouth. The distance from the colliery to Cardiff, the shipping port, is 22 miles, to which there is conveyance both by railroad and canal. No current price is given in the return, which states "that the coal has been shipped largely to the West Indies under contract with the government for steam purposes, and has also been sent to the Mediterranean and America, and has given much satisfaction."

This is a coal of rather a soft description, easily breaking up into small pieces with a bright appearance of fracture, but which is somewhat obscured by the apparent irregularity of its structure. It contains a considerable proportion of a white substance, but no iron pyrites were observed in it. Some portions of the coal, where the structure is well seen, show the lines of fibrous structure as perpendicular to the planes of deposition or bedding. Numerous very thin layers of a soft brownish substance are seen along the line of bedding.

Our remarks during the trials show that it kindles very readily and burns freely, raising the steam with great rapidity. It makes a remarkably clean fire, without any smoke, opening well on the bars without caking. No clinkers were made: the ashes and cinders left were clean, and of a whitish colour.

	December 10. 1st day.	December 11. 2d day.	December 12. 3d day.
Fire lighted	8 h. 15 m.	8 h. 10 m.	8 h. 15 m.
Steam up	9 h.	9 h. 15 m.	9 h. 20 m.
Weight of wood used	10 lbs.	10 lbs.	10 lbs.
Initial temperature of water in boiler	200°	205°	209°
Temperature of water in tanks	42°	34°	33°
Barometer	—	—	—
Extremes of external thermometer	—	—	—
Extremes of internal thermometer	54—66°	48—62°	42—54°
Dew-point	—	—	—
Area of damper open	112 in.	112 in.	112 in.
Weight of coals consumed	337·5 lbs.	309·5 lbs.	321 lbs.
Weight of ashes left	8·5 lbs.	11·5 lbs.	16·5 lbs.
Per centage of combustible matter in ashes	52·76 lbs.	—	—
Weight of cinder left	8·5 lbs.	12·5 lbs.	12·5 lbs.
Per centage of combustible matter in cinder	89·74	—	—
Weight of clinker in cinder	None.	None.	None.
Average weight of soot in flues	1 lb.	1 lb.	1 lb.
Per centage of combustible matter in soot	51·39	—	—
Weight of water evaporated	2,876 lbs.	2,629 lbs.	2,793 lbs.
Weight of water evaporated from 212° by 1 lb. of coal	10·07 lbs.	10·07 lbs.	10·307 lbs.
Weight of coals per hour for 1 square foot of grate surface	8·43 lbs.	7·74 lbs.	8·01 lbs.
Duration of experiment	8 hours.	8 hours.	8 hours.
Specific gravity of coal	1·326	—	—
Mean weight of cubic foot of coal	53·22 lbs.	—	—
Economic weight or space occupied by one ton	42·09 cu. ft.	—	—
Cohesive power of coal	56·2	—	—

In reviewing this long and elaborate inquiry, the Commissioners state that the qualities which distinguish particular kinds of fuel are very varied, so that it is difficult to deduce general results. In the one

(1) This cock was used for blowing off the water, which was frequently done, in order to cleanse the boiler: for since the water contained on an average 20 grains of fixed matters per gallon, and from 300 to 400 gallons were daily evaporated, the boiler would otherwise have become rapidly coated with a residue which would interfere with and modify the experiments.

economical application of coals, *viz.* their evaporative value, one variety of coal, which may be admirably adapted from its quick action for raising steam in a short period, may be far exceeded by another variety, inferior in this respect, but capable of converting a much larger quantity of water into steam, and therefore more valuable in the production of force. A coal uniting these two qualities in a high degree might still be useless for naval purposes, on account of its mechanical structure. If the cohesion of its particles be small, the effect of transport, or the attrition of one coal against another by the motion of a vessel, might so far pulverise it as materially to reduce its value. Even supposing the three qualities united, rapidity and duration of action with considerable resistance to breakage, there are other properties which should receive attention in the selection of a fuel, without the combination of which it might be useless for our steam navy. With respect to the bulk or space occupied by certain weights of different coals, two varieties of coals often equally good as regards their evaporative value, may differ as to the space occupied as much as 20 per cent.; that is, where 80 tons of one coal could be stowed, 100 tons of another of equal evaporative value might be placed by selecting it with attention to its mechanical structure.

The various specimens of coals sent from different parts of the country were first analysed and examined in the laboratory, but as it was found that no practical result could be attained by this method alone, it was determined to test each variety of coal on a scale of sufficient magnitude to check the theoretical views by the practical results.

In ascertaining the true evaporative value of the fuel, several corrections were necessary before the final result could be arrived at. Some of these have been already noticed. Other circumstances also affect the evaporative powers of the coal, as for example, that all the water exposed to the action of the fire in the boiler is not converted into steam, and that wood is used to light the fire. The expansion or contraction of the boiler from an increase or diminution of the temperature, made a difference of nearly 70 lbs. of water in the contents of the boiler between the temperatures of 150° and 212°: allowance was therefore made for this even when the difference between the initial and final temperature was not greater than 10°. Other circumstances of less importance were neglected, such as the quantity of gases evolved during combustion, the elevation in temperature of the air entering the fireplace, the barometrical and hygrometric conditions of the atmosphere, the radiation from the boiler, (very small in amount, owing to its brick covering,) the hygrometric state of the fuel, or the heat necessary for obtaining mechanical draught in the chimney. With respect to the hygroscopic condition of the fuel, had wood been employed correction must have been made for it, but the hygroscopic nature of coal is very much less than that of wood. The latter contains $\frac{1}{5}$ of its own weight of hygroscopic water; and the heat necessary for the evaporation of this quantity might be shown by a simple calculation to be nearly equal to 22 per cent. of the total heat obtained by the combustion of the wood. The hygroscopic water in coal is however very small, as will be seen by the following determinations of some of the Welsh specimens experimented upon:—

	Hygroscopic water.
Graigola coal . . .	1·06 per cent.
Anthracite	2·44 „
Old Castle	0·74 „
Ward's Fiery Vein . .	1·27 „
Myndd Newydd . .	0·67 „
Pentrepoth	0·78 „
Pentrefetin	0·70 „

Of the gases flying up the chimney, repeated analyses proved them not to contain any combustible constituent; the only products ever found being carbonic acid, sulphurous acid, oxygen, and nitrogen. The quantity of free oxygen in the chimney varied from $\frac{1}{4}$ to $\frac{1}{2}$ of the oxygen which combined with the fuel; in other words, nearly twice as much air passes through the fire as is strictly necessary by theory.

The heating values of coals depend on the quantity of oxygen required for their complete combustion. This may be estimated experimentally by heating the coal, with certain precautions, with an excess of litharge, or it may be determined by calculation from the known equivalents of the combustible ingredients of the coal. From the quantity of lead reduced by the coal, the oxygen employed in its combustion may be estimated, and the calorific values stand in direct relation to this quantity. The amount of oxygen necessary to consume the combustible constituents may be more accurately determined by elementary analysis; and thus calculated, the results are generally found to be about one-ninth greater than those indicated by experiment with the litharge. The calculation from the elementary analysis depends upon the circumstance that 6 parts or 1 equivalent of carbon require 16 parts or 2 equivalents of oxygen for combustion, while 1 part of hydrogen requires 8 parts of oxygen; it is only necessary, therefore, to subtract from the hydrogen a quantity corresponding to the oxygen contained in the coal, to enable the calculation to be made on these principles. As the calorific values are only relative, it is useful to refer them to the heating power of pure carbon, 1 part of which requires 2·666 parts of oxygen for combustion, and is capable, according to Despretz, of heating 78·15 parts of water from its freezing to its boiling point. The calculation may be simplified by multiplying each part of lead obtained by 2·265, which gives at once the weight of water capable of being heated between these temperatures by a unit of the coal used in reducing the litharge.

The economical values of coal are often influenced by circumstances which cannot be taken into account in chemical analyses. If, for example, the coal in the furnace should undergo destructive distillation before combustion commences, a large quantity of the constituents of the coal are rendered gaseous, and so much heat is expended in this act, that the heat

developed by the subsequent combustion of these gases is frequently not greater than that abstracted during their formation. It would have been difficult to ascertain the proportion of fixed and volatile products in the various coals; this, however, was done in certain cases, of which a tabulated list is given, showing the per centage of coke, tar, water, ammonia, carbonic acid, sulphuretted hydrogen, olefiant gas, and hydro-carbon, and other gases of an inflammable nature. Nor was it necessary to state the proportion of the fixed and volatile products, the per centage of coke being the chief point to be determined. [See the table in article COAL, p. 384.]

It has been supposed that the evaporative value of a bituminous coal may be expressed by the value of its coke, the heat of combustion of its volatile products being practically little more than is necessary to volatilise them. If this supposition were even near the truth, the most useful practical results might follow from it. By a larger and better applied system of gas manufacture, the volatile products of distillation might be made useful not only for the purposes of illumination, but also for domestic heat, and the residual coke might be used with an equal economy in our manufactures,[1] thus preventing the emission of that smoke which at present is so destructive to the comfort of our large cities. It is easy from analysis to examine whether the duty performed by the coal is to be attributed to its fixed ingredients, or coke, by estimating the work which the latter is capable of performing. This may be done by subtracting the amount of ashes in the coal from its amount of coke, and estimating the remainder as carbon. This carbon multiplied by its heating power, 13,268, and divided by 965·7, or the latent heat of steam, indicates the number of pounds of water which the coke by itself could evaporate without the aid of the combustible volatile ingredients of the coal.

The whole system of manufacturing coke is at present very imperfect. Besides losing the volatile combustible substances, which under new adjustments might be made of much value, an immense quantity of ammonia is lost by being thrown into the atmosphere. Ammonia and its salts are daily becoming more valuable in agriculture, and it is their comparative high price alone which prevents their general use in all kinds of cereal cultivation. By a construction of the most simple kind, the coke ovens now in use might be made to economise much of the nitrogen which invariably escapes in the form of ammonia. The price of sulphate of ammonia is about 13*l.* per ton, and in coking 100 tons of coal about six tons of this salt may be produced.

By the data furnished by this report, the actual value of the coals may be contrasted with that which is theoretically possible, supposing their combustion to proceed under circumstances which prevented any loss of heat. The actual duty obtained by a pound of coal from the boiler employed may be easily expressed by the number of pounds raised to the height of one foot. This result may be readily obtained by the simple formula—

$$W \eta \times 965{\cdot}7 \times 782 = x.$$

W representing water, of which η pounds are evaporated by a pound of coal. This formula is deduced from the fact that η pounds of water multiplied by 965·7, or the co-efficient for the latent heat of steam at 212°, indicates the number of pounds of water which would be raised 1° Fahr.; and the number 782 arises from experiment on the mechanical force denoted by the elevation of a pound of water 1° Fahr.; that force being equal to 782 pounds raised to the height of 1 foot, according to the careful experiments of Mr. Joule on the friction of oil, water, and mercury.

The best Cornish engines are said to be capable of raising 1,000,000 pounds to the height of one foot for every pound of coal consumed; this is only about $\frac{1}{8}$th of the actual force generated, and only $\frac{1}{11}$th or $\frac{1}{12}$th of the theoretical force. The various experiments made on boilers with regard to the evaporative power of coal have not given uniform results. Smeaton in 1772, with one pound of Newcastle coal, evaporated 7·88 lbs. of water from 212°; Wall, in 1788, fixed the quantity at 8·62 lbs.; Wicksteed, in 1840, found that 1 lb. of Merthyr coal could be made to evaporate 9·493 lbs. of water from 80°, which is equal to 10·746 lbs. from 212°. In some experiments made on the boiler of the Loam's engine at the United Mines in Cornwall, each pound of coal was found by a trial of six months to evaporate 10·29 lbs. of water from 212°. It has been stated that 14 lbs. of water have been evaporated by 1 lb. of coal burned in Cornish boilers, but as this is the utmost quantity theoretically possible, the statement requires to be reconsidered. According to some experiments undertaken in Cornwall, at the request of the commissioners, it was found that 11·42 lbs. of water were evaporated by every lb. of Welsh coal corresponding in composition to that of Mynydd Newydd.

With regard to the patent fuels, although their specific gravity is lower than that of ordinary coals, yet from their brick-like shape and mechanical structure they generally occupy less space than an equal weight of coals. Many of the patent fuels, however, are made up of the dust of bituminous coal, cemented together with bituminous or tarry matter. They would more nearly resemble the best coals by mixing a more anthracitic coal with the tar. But according to the practice indicated, it would be almost impossible to prevent the emission of dense opaque smoke. Besides this, the very bituminous varieties are not well suited to hot climates, and are as liable to spontaneous combustion as certain kinds of coal. To avoid these inconveniences some kinds of patent fuel are subjected to a sort of coking.

It is important to obtain exact information respecting the effects likely to be produced on coals by stowage and continued exposure to high temperature. The coals may not only deteriorate under such circumstances, but emit inflammable gases,

(1) In this case it would be necessary not to carry on the process of distillation so far as at present, as the residual coke would be more combustible and the gases purer.

and produce dangerous explosions. Coal at ordinary temperatures evolves carbonic acid and nitrogen, together with inflammable gases, showing that a slow combustion or decay is going on in consequence of exposure to the oxygen of the atmosphere. This change in coal takes place more rapidly at an elevated temperature, as in hot climates, and it is also greatly favoured by moisture. When sulphur or iron pyrites is present in considerable quantity in a coal still changing under the action of the atmosphere, a second powerful heating cause is introduced, and the coals may spontaneously take fire. The best method of prevention is to dry the coals thoroughly before they are stowed away, and to select a variety of fuel not liable to the progressive decomposition above alluded to.

If the coal be kept in iron bunkers and be liable to be wetted with sea-water, the iron will become speedily corroded, in consequence, apparently, of the carbon or coal forming with the iron a voltaic couple, and thus promoting oxidation. The action is similar to that of the tubercular concretions on the inside of iron water-pipes when a piece of carbon not chemically combined with the metal and in contact with saline waters produces a speedy corrosion. A mechanical protection is sometimes sufficient, such as a coat of Roman cement, a lining of wood, or drying oil, driven into the pores of the iron with great pressure.

FULCRUM. See Lever.

FULLER'S EARTH, a kind of lithomarge clay of a greenish or yellowish grey colour; it is soft and friable, coarse or fine grained, with a greasy feel; its sp. gr. varies from 1·8 to 2·2. It forms a non-plastic paste with water. Its constituents are, according to Dr. Thomson's analysis, silica 44 per cent., alumina 23·06, lime 4·08, magnesia 2, protoxide of iron 2, water 24·95. Hence, supposing the lime, magnesia, and iron to be in the state of silicates, as accidental ingredients, fuller's earth is a hydrous bisilicate of alumina, and two equivalents of water. It was formerly much used in the cleansing of woollen cloth in the operation of *fulling*, whence the name; its cleansing action depending on the affinity of its alumina for greasy matters. The fullers generally use it before they apply soap. Fuller's earth is found in several parts of England, but chiefly in Surrey, Kent, Bedfordshire, Hampshire, Bath, Nottinghamshire, and Sussex. At Nutfield, near Reigate, in Surrey, it occurs in regular beds, near the summit of a hill, between beds of sand or sand-stone, containing fossil wood, cornua ammonis, &c. There are two distinct beds of fuller's earth; the upper is of a greenish colour, and is 5 feet in thickness; this rests upon the other bed, which has a bluish tint, and is 11 feet in thickness. Masses of sulphate of barytes, often in regular crystals, are found in these beds, particularly in the latter.

The earth is prepared by baking, or, where fuel is scarce, by heating in the sun; it is then thrown into cold water, when it falls into powder. The separation of the fine from the coarse powder is effected by the simple but beautiful operation of *washing over* (as described under Emery, p. 594), three or four tubs being used for the purpose. The different kinds of earth thus obtained are used for cleansing fine or coarse cloth.

FULLING. See Hat—Wool.

FULMINATING POWDER. This may be prepared in various ways; as for example:—a mixture of 3 parts nitre, 2 of dry carbonate of potash, and 1 of sulphur, forms a fulminating powder, a small portion of which placed on a metal plate, and heated to about 330° will blacken, fuse, and explode with violence in consequence of the rapid action of the sulphur upon the nitre, and the sudden evolution of nitrogen and carbonic acid, the residue being chiefly sulphate of potash. The fulminating powder used in percussion caps is prepared from Mercury, and will be described under that head. Fulminating powders from Gold, Silver, and Platinum will be noticed in the articles on those metals.

FULMINIC ACID. An acid existing in certain fulminating compounds: it has not yet been isolated: it will be noticed in the description of the process for preparing fulminating powder under the article Mercury.

FUMIGATION is an application of vapours or fumes for the purpose of getting rid of unpleasant or unwholesome smells. By the old method, vapour of hot vinegar, aromatic pastiles, and vegetable matters, the smoke of burning brown paper, burnt feathers, tobacco, &c. were supposed to be effectual; and one or other of these substances is still occasionally employed; but in all these applications little more is done than to substitute one bad smell for another, by overpowering, not displacing or destroying the bad or dangerous odour; and in the case of tobacco, its reputed purifying and antiseptic properties furnish an excellent excuse to those who have the misfortune to smoke, of rendering the house always unpleasant, and not at all more free from infection. The only efficacious kinds of fumigation are by means of gases which decompose the miasmata or fumes, and convert them into innocuous compounds: such gases are sulphurous acid, muriatic acid, nitrous acid, and chlorine; the last named, either in its free state or in combination with lime, or soda, being incomparably the most convenient, efficacious, and powerful. [See Chlorine.]

Sulphurous, and the other gaseous acids, are supposed to perform, indirectly, important service in maintaining a large city like London in a healthy condition. The products of the combustion of coal may operate in checking the spread of malignant diseases; the manufactories of chloride of lime and other chemical works may also be of use, although the benefit derived from them is seriously counteracted by trades which deal largely in the conversion of refuse animal matters; and were it not for the sewerage of London (imperfect though it be) and the water companies, the effects of our large consumption of animal food, and the presence of slaughter-houses in every parish, would be more severely felt. In

times of plague and other pestilence the vicinity of smelting furnaces was formerly resorted to as being least liable to infection, the sulphurous and other acid fumes acting as disinfectants.

The theory of infection and contagion is very imperfect, and therefore the mode of action of disinfectants must be equally so. We are ignorant of the influence and production of malaria, of marsh miasma, and other poisonous exhalations of organic, but chiefly of vegetable, origin, which produce that extraordinary disease the ague, or intermittent fever. One of the most remarkable properties of some forms of infectious matter is its permanency, retaining, as it frequently does, its peculiar powers for a long, if not for an indefinite, period. Of this, the preservation and transmission of dried variolous and vaccine matter is a familiar example. Professor Brande states, that "the infection of scarlet fever is sometimes retained for weeks and months by articles of wearing apparel; in one instance, after a malignant form of that disease had prevailed in a house, it was fumigated with chlorine and whitewashed, and every article of furniture and clothing cleansed and fumigated, with the exception of a handkerchief, which had been accidentally overlooked, and to which the appearance of the disease, after a period of two months, was probably attributable. Blankets and woollen goods seem especially retentive of such poisons, and in all doubtful cases should be burned."

In 1825 Dr. Faraday was employed to fumigate the Penitentiary at Millbank, London. The space requiring fumigation amounted to nearly 2,000,000 cubic feet, and the surface of the walls, floors, ceilings, &c., was about 1,200,000 square feet. This surface was principally stone and brick, most of which had been lime-washed. The fumigation was performed by means of chlorine generated in the following manner. A quantity of salt in powder was mixed with an equal weight of black oxide of manganese, and upon this mixture was poured a cold solution of 2 parts of sulphuric acid and 1 part water. The acid and water were mixed in a wooden tub, the water being first put in, and it being more convenient to measure than to weigh the water and acid, 10 measures of water and 9 of acid were used: half the acid was added first, the remainder being added when the mixture was cold. $3\frac{1}{3}$ lbs. of the mixture of salt and manganese were put into a common red earthen pan, of the capacity of about a gallon, to which a measure equal to $4\frac{1}{2}$ lbs of the dilute acid was added: the mixture was then well stirred and left to itself. A number of these pans, each containing a similar dose, being thus arranged, all the apertures were closed, and as the action did not commence immediately, the operator could pass from pan to pan without inconvenience from the suffocating fumes of chlorine. On entering a gallery 150 feet in length, a few minutes after the mixture had been made, the general diffusion of chlorine was evident; in half an hour it was often almost impossible to enter, and frequently, on looking along the gallery, the yellowish green tint of the gaseous atmosphere could be perceived. Up to the fifth day the colour of the chlorine could generally be observed in the building: after the sixth day the pans were removed, though sometimes with difficulty, and the gallery thus fumigated had its windows and doors thrown open. The charge contained in each pan was estimated to yield about $5\frac{1}{2}$ cubic feet of chlorine: in fumigating the space of 2,000,000 cubic feet, about 700 lbs. of common salt and the same of black oxide of manganese were employed, yielding about 1,710 cubic feet employed to disinfect this space. In ordinary cases Dr. Faraday conceives that from $\frac{1}{2}$ to $\frac{1}{4}$ this quantity of chlorine would suffice.

FUNNEL, a hollow conical vessel, with a small pipe issuing from its apex, used for conveying fluids into vessels of small apertures: it is also of use in filtering. [See FILTRATION.] For domestic purposes funnels may be made of copper, pewter, or tin-plate; but in the laboratory no funnel made of a material likely to be corroded by acids or alkalies should be allowed: the funnels should be of glass, earthen, or stone-ware.

FUR, a material for warm clothing, largely required by the inhabitants of cold countries, where it is also most richly supplied; for it consists of the skins of such animals as are covered for their own protection with thick, soft hair; and the colder the country, the more abundant the provision thus made for them. The skins taken from these animals, when properly prepared on the inner side, are extremely durable, often very beautiful, and form the most comfortable description of clothing which can be worn in severe climates. In the prepared state, the skins are called fur; but without any preparation, they go by the commercial name of *peltry*.

The extensive and almost universal employment of fur as an article of dress, during our own comparatively mild winters, will give some idea of the demand for this material in less favoured climates. In Russia, Poland, East Prussia, Hungary, Bohemia, Saxony, &c., lambs' skins constitute an essential part of the dress of thousands among the lower classes, and the skins of various other animals may also be considered as articles of absolute necessity. The principal consumption of the more beautiful and costly furs, which rank as articles of fashion and luxury, is in China, Turkey, Russia, and England.

So early as the sixth century, the skins of sables formed an article of fashionable attire at Rome, and were brought from the confines of the Arctic Ocean, at great cost, to supply the demand of that wealthy capital. Several centuries elapsed, however, before Western Europe sought after a similar luxury. The traders of Italy brought a considerable supply to England in the time of Edward III.; so much so, that the monarch thought fit to prohibit their use, except among the wealthier classes.

The Canadian fur trade was commenced by the French, soon after their settlement on the St. Lawrence, and was at first extremely profitable, because the Indians, unconscious of the worth of the skins, would readily exchange them for beads, nails, hatchets, trinkets, and other articles of in-

adequate value. At first there was also an almost unlimited supply; but when the hunting-grounds in the neighbourhood of the European settlements became exhausted, longer journeys were necessary, and various settlers, under the name of *coureurs des bois*, or wood-rangers, made excursions to more distant hunting-grounds, sometimes remaining there for many months, adopting the habits of the Indians, and forming connexions with them. But the measure of success attending this branch of traffic soon brought other speculators into the field. A company was formed in London, and chartered by Charles II. in 1670, for the purpose of trading in fur with the Indians inhabiting the region to the north and west of Hudson's Bay, and hence called the Hudson's Bay Company. This association became prosperous, founded many establishments, and carried on its trade with success for more than a century. It then met with a powerful competitor in a new company, consisting of wealthy and influential British settlers in Canada, and others, who recognised no exclusive right in the Hudson's Bay Company to trade in a particular region; the charter granted to them never having been confirmed by Act of Parliament. This second company (called the North-west Company) carried on its affairs with great spirit and energy, having its chief establishment at Montreal, but trading upwards of four thousand miles further to the north-west. Where these companies came in contact, animosities arose, which occasionally led to the commission of actual violence between the servants of each. After a long course of dissention, the two companies at length united into one powerful body, under the name of the Hudson's Bay Fur Company, which now engrosses the principal part of the fur trade of British America. The Indian trade of the great lakes and the Upper Mississippi is principally enjoyed by the North American Fur Company, whose chief establishment is in New York. But we are told that, with the exception of the musk-rat, most of the fur-bearing animals are exterminated in the vicinity of the lakes.

A large supply of furs is, therefore, received through the Hudson's Bay Company, whose immense hunting-grounds afford a varied and almost endless amount of valuable skins, and whose possessions, or the lands over which they claim control, extend to nearly one-eighth of the habitable globe. The great fur-sales of this company are held in London every year, during the month of March, and attract great numbers of foreigners. Through their means the greater part of the furs destined for the Continent find their way to the great fair at Leipsic, whence they are distributed throughout Europe. In former days, the beaver was one of the most valuable furs of this company; but it is of far less importance at the present time, because the principal use to which it was applied, in the manufacture of hats, is now greatly diminished. But by a new process, and by the application of an ingenious machine, the skin of the beaver is now cut, and converted into a handsome fur for ladies' use. There has also been a successful attempt to employ its fine silky wool for weaving purposes. The skin of the black and silver fox is highly prized in the Russian and Chinese markets, and is the most valuable of that family; but the red fox is also used by the Chinese, Persians, Greeks, &c., as linings and trimmings for robes, which are ornamented in spots or waves with the black fur of the paws of the same animal. The white and blue fox is also used for ladies' wear. The finest raccoon furs are also the produce of North America. They are extensively used in Russia and throughout Germany, as a lining for gentlemen's coats, the darkest skins being preferred.

The Hudson's Bay martin, or sable, is a valuable and useful fur, and is used in large quantities in this country, and in France and Germany. So is also the mink, which is exclusively the produce of that company's possessions and of North America. The fur of the wolf is also used in cold countries for cloak-linings, coverings of sleighs, &c. The soft, warm, and light fur of the lynx is also in much request for linings, &c. In its natural state it is greyish-white, with dark spots; but to prepare it for certain markets it is dyed of a beautiful glistening black. The heavy fur of the sea-otter is of great commercial value, and is said to be the royal fur of China. It is worn by officers of state, mandarins, and other important persons: it is also held in great esteem in Russia for facings, trimmings, collars, &c. of gentlemen's dresses; but it is unfit for ladies' wear, on account of its great weight. The fur of the North American black bear is valued for military purposes at home and abroad. It is formed into caps, rugs, pistol-holders, hammercloths, sleigh-coverings, &c. The fur of the brown bear is used by American ladies. The musquash, or musk-rat, is also imported into this country in great numbers. It was formerly used in the hat manufacture, but now, with some preparation, is converted to the ordinary purposes of fur. The Hudson's Bay otters are chiefly procured for Russia and Greece, where they are used for caps, collars, &c.

Important as is the trade thus carried on with the New World for the furs of her northern countries, yet there are some furs, and those the most costly, and highly esteemed among ourselves, for which we are indebted to Northern Europe and Asia, the great trade in them being carried on by Russia. The ermine is one of these, a fur which is produced in many countries, but only in perfection in Russia, Sweden, and Norway. The animal producing it is the stoat or weasel of southern climates, but its peculiar value, in this instance, arises from a provision of nature, by which the animal becomes pure white in winter, in those snow-covered regions, where it would otherwise be exposed more clearly to the view of its enemies.[1] The ermine, therefore, must

(1) The effect of cold on the fur of the Hudson's Bay Lemming, was made the subject of an experiment during Ross's voyage. The little creature was kept in a cage during several months in the warm cabin, during which time it retained its summer fur It was determined to try the cruel experiment of exposing it on deck, at night, to a temperature of 30° below zero. After one night's exposure, the fur on the cheeks, and a patch on each

be sought and killed in winter, to produce the celebrated fur, which is the royal fur of England, as it is also of Russia, Germany, Spain, Portugal, &c. The tail, alone, of the animal is jet black at the tip, and this, in ordinary wear, is inserted at intervals in the fur, as an ornament. There is no restriction on the wearing of this fur in England at the present day, but in the reign of Edward III. it was expressly forbidden to all but the royal family (a similar prohibition still exists in Austria). There is, however, a distinction made in the mode of ornamenting the fur as employed on state occasions, according as it is to be worn by the sovereign, or by peers, peeresses, judges, &c. The sovereign, and members of the royal family can alone wear ermine trimmings to their robes of state, in which the fur is spotted all over with black —a spot in about every square inch of the fur. These spots are not formed of the tail of the ermine, but of the paws of the black Astracan lamb. Peeresses wear capes of ermine, in which the spots are arranged in rows, the number of rows denoting their degrees of rank. Peers wear robes of scarlet cloth trimmed with pure white ermine, without any spots. But the number of rows or bars of pure ermine in this case, also denotes the rank. The robes of judges are also scarlet and pure white ermine. In heraldic language, this fur is called *minever*.

The ermine is a small animal, the extent of the skin, exclusive of the head and tail, not being above ten or twelve inches. The best fur is furnished by the oldest animals, which are taken either in snares and traps, or by shooting at with blunt arrows. The skins are always sold in lots of forty, called the timber.

Next in value and general use are Russian sables, the best of which are extremely costly and beautiful.

These are used for civic robes, &c., as the ermine is for court and parliamentary dresses. The lining of a robe of state, if made of the finest sables, may be worth a thousand guineas. Skins of the best quality are procured by the Samoieds, and in Yakutsk, Kamschatka, and Russian Lapland. The length of the animal (which by some naturalists is considered to be a variety of the pine-marten) is from eighteen to twenty inches. The darkest in colour are considered the most valuable. The produce of Russia in these costly and beautiful skins, is about twenty-five thousand annually. The tails of sables are used in the manufacture of artists' pencils or brushes. A great quantity of mink-sable, which, as we have said, is exclusively the produce of the Hudson's Bay Company's possessions, is sold to the inexperienced as real Russian sable. There is an inferior sable called Kolinski or Tartar sable, which is procured from Russia. The animal belongs to the weasel tribe, and is of a bright yellow colour. This fur, when dyed, is sold among the cheaper sables, but it is also much used in its natural state.

The fur of the squirrel is exported from Russia in immense and almost incredible quantities, the produce of that country being estimated at about twenty-three millions of skins annually. This country alone received from thence, during the year 1850, upwards of two million skins. The back of the grey squirrel is most in request, but the white portions, from the belly of the same animal, are also largely used for linings, &c. The favourite Weisenfels cloak-lining is made from the white part of the dark blue squirrel, and is so extremely light, that the lining for a full-sized cloak does not weigh more than 25 ounces. It is known as the *petit gris*. The lamb-skins of Russia are celebrated, especially the skin of the Astracan lamb, which is fine, rich, and glossy like silk, and is said to be obtained from the immature animal, the parent sheep being destroyed to obtain it. Of the Persian grey and black lamb it is also averred, that the animal is sewn up tightly in leather as soon as it is born, that the small curls which cover the skin may not expand. The national dress of Hungary is made of the lambs'-skins of that country, worn in summer with the fur outside, in winter the reverse. The skin is tanned in a peculiar way, and ornamented according to the fancy of the wearer. The short jacket worn by Spaniards, is of lambs'-skin, decorated with filligree silver buttons.

The skins of hares and rabbits are used in common with beaver and nutria (or coypou) skins for felting purposes; they are also dressed and dyed for conversion to various other uses. Rabbits' fur is made into a cloth for ladies' use; the skins of the finer sorts of rabbit are much employed for linings, &c., the skin of the white Polish rabbits forming no mean substitute for ermine. The silver-grey rabbit formerly peculiar to Lincolnshire, but now bred in warrens in other parts of the country, is invariably exported to China and Russia, where it is in great demand, and secures a high price. It has been remarked as a peculiar feature of the fur-trade, that almost every country or city which produces and exports furs, imports and consumes the fur of some other place frequently the most distant. An article is seldom consumed in the country where it is produced, but is eagerly sought after in another quarter of the globe. A suit of English silver-grey rabbit is rarely seen here, and when exhibited, is far from securing the admiration which it meets with in China.

Other skins in less general use are the chinchilla, introduced about forty years since from South America, where it is exclusively found; the fur seal, divested of its long coarse hair, and retaining the curly, silky, yellow down, which, when died of a rich brown colour, supplies a fur of velvet-like softness; the tiger, used to cover seats of justice in China, and also employed for rugs, &c.; the leopard, worn as a mantle by the Hungarian nobles who form the royal

shoulder, had become perfectly white. On the second day, those patches had extended, and the posterior part of the body and flanks had turned to a dirty white. During the next four days, the changes continued, and at the end of a-week, the animal was entirely white, with the exception of a dark band across the shoulders. The animal at length died from the severity of the cold, and in examining the skin, it appeared that all the white parts of the fur were longer than the unchanged portion, and that the ends of the fur only were white so far as they exceeded in length the dark-coloured fur; and by removing these white tips with a pair of scissors, it again appeared in its dark summer dress.

body-guard; used also as an officer's saddle-cloth by some of our own cavalry regiments; the Angora goat, whose long silky coat once formed a costly article of ladies' wear, but is now of small value, and is chiefly used for carriage and drawing-room mats and rugs; buffalo skins, which have been of late years much used in Europe as robes and wrappers in severe climates; the cat, which, when bred for the purpose, as it is largely in Holland, supplies a useful and very durable fur.

Substitutes for fur have been found in the plumage of birds; thus swan's-down, goose-down, egret-down, and the silvery plumage of the grebe, are convertible to ladies' use. The down from the bird called the egret is so rare and costly, that four sets only have been made during a century, the last having been fabricated in Paris for the Great Exhibition in Hyde Park.

The dressing or preparing of furs for use, is a very simple operation when the furs are to remain on the original felt, and to be worn as garments, trimmings, &c. In early times, the skins were worn nearly in the state in which they were taken from the animals, but as the wearing of fur gradually became a matter of fashion, instead of a mere matter of convenience or necessity, so the preparation of it was more carefully attended to. The first process belongs to the hunter, who, on capturing a fur-bearing animal, strips off the skin, and hangs it up to dry in the open air, or in a cool room without a fire. If the skin be well dried, and carefully packed, it reaches its destination, however distant, in excellent condition; but if any moisture be left, or if it be packed with skins less carefully dried, so that the slightest degree of putrefaction takes place, then the fur is unfit for use, so far as the furrier is concerned. A minute examination of the skins is therefore his first business; after which, his next care is to cleanse them from greasiness, by steeping the skins in a liquid containing bran, alum, and salt, and then working and scouring them in the same. But this process does not entirely remove a kind of oil which is found in the fur itself. This is removed by an application of soda and soap. Finally, the skin is washed in clear water and dried, the previous treatment having effected a kind of tanning process, and converted it into thin leather, adapted to be cut up into articles of dress. The cutting up of the skins requires some judgment, to avoid waste. It is well known, that the fur of an animal is scarcely ever of the same colour all over the surface, the back usually presenting the darkest and richest colour, and the under parts a much lighter hue. In cutting out material for muffs, mantles, &c., the same harmonious colour is required throughout, therefore the best portions of several skins, corresponding in quality and colour, must be selected, and the rest refused. But this refuse, if not cut to waste, is equally available for making articles of a less costly description, and the skill in joining these pieces, even to the smallest portion, so that they shall appear as one skin, is not a little remarkable. Many a lady, on having her furs fresh lined under her own superintendence, has viewed, with surprise approaching to dismay, the elaborate patch-work which the skins present on their inner side.

Skins that are to be used in felting, as hare, rabbit, beaver, nutria skins, &c., undergo a longer process. Hares' fur is first cleaned on the outside with a tool called a rake, then damped on the inside, and several pressed together to remove creases. Next, the longer portion of the hair, which has no felting property, is carefully sheared off without injuring the soft thick fur beneath. The skin is then stretched out on a cutting-board made of willow, and kept damp. A knife about six inches long by three broad is then applied in the direction the fur naturally lies, and gradually removes it from the pelt in a light fleecy mass. In preparing rabbit-skin, the long hair is pulled out by a short knife, the thumb of the operator being protected by a leather shield. The skin also requires careful cleaning, on account of its greater greasiness. The inner cuticle is stripped off, and the surface beneath it rubbed with whitening.

A somewhat similar process is adopted with beavers' skins, which are so full of grease, that nothing but a thorough scouring with fuller's earth and whitening will bring them into condition. In these also the long hairs are removed by pulling out; the under fur, however, is not removed by hand. A machine has been contrived, by which a broad and sharp blade, of the full width of the skin, falls rapidly, and with a chopping action, near the edge of another blade beneath. The skin is fastened to a part of the machine which draws it between the blades from end to end, and as it passes along, the fur is completely cropped from the pelt without any injury to the latter. Falling on an endless apron, the fur is removed, and transferred to a large chest, where it is powerfully acted on by a fan, which revolves two thousand times in a minute, carrying the fur along a hollow cylinder or channel fifty feet long. As it passes, the fur becomes separated into different qualities, simply by its own specific gravity. The largest and coarsest hairs fall first, the next further on, and so on, the finest being carried to the extreme end. The pelt of the beaver is very smooth and uniform, therefore the fur can be conveniently removed by the above machine; but for other and less regular skins, it is found inapplicable. Nutria skins are subjected to thorough washing and purification with soap and boiling water, being full of fat and oily matter. These skins resemble, in some degree, those of the otter; and in fact, the name commercially given to them is derived from the Spanish word for "otter." Several other kinds of fur have been turned to felting purposes with inferior effect, such as the fur of the mole, musk-rat, seal, and otter. The felting property can be increased by wetting the skin on the inner side with dilute sulphuric acid, while yet the fur remains upon it, and then quickly drying it near the fire, or by passing a hot iron over it. This process is called *carrotting*, from the colour it imparts to the fur.

FURNACE, (Latin, *fornax*,) an enclosed fire, differing from the common grate in the mode by which the draught is supplied: for while in the com-

mon grate the air rushes in through the front as well as the bottom bars, it is supplied in the furnace at the bottom only, and that with considerably increased velocity compared with the common grate.

Numerous forms of furnace are employed in the Useful Arts: some of them have already been described; others will be noticed hereafter. In the laboratory "there is scarcely any limit," as Dr. Faraday remarks, "to the number of furnaces that have been contrived as particularly adapted either for special or general uses; all, no doubt, were good at the time they were devised, and superior, for some reason or other, to those which had preceded them; but the character of chemical operations has changed so much as to render many of these contrivances useless, or of little importance, and each person is now left to select those which are most agreeable to himself, as according best with either his notions or modes of experimenting." The general working furnace of the laboratory is thus described by the same excellent authority:—"Its use is partly domestic, partly chemical; for it has to warm and air the place occasionally, to heat water, as well as to supply the means of raising a crucible to ignition, or of affording a high temperature to flasks through the agency of a sand-bath. These objects are best obtained by those furnaces which are built with a table-top. The fire-place itself is constructed of brick-work with iron front and fittings, and the flue being conveyed horizontally for 3 or 4 feet, is afterwards carried off to, and connected with, the main flue existing in the wall. The fire-place and horizontal flue are covered with a large plate of cast-iron of from 2 to 3 feet in width: this is formed in the middle, over the heated part, into sand-baths, a round movable one over the fire itself, and a long fixed one over the flue. The sand-baths supply every gradation of heat, from dull redness, if required, down to a temperature of 100°, or lower; whilst on each side of them exists a level surface which answers every purpose of an ordinary table, and supplies extraordinary facilities to experiments going on in the sand-bath or furnace. Nor are these advantages gained by any serious sacrifice of heating power in the furnace itself, for it is easy so to construct it as to make its ordinary combustion not more rapid than that of a common fire, and yet, by closing the fire-door and opening the ash-pit, to obtain a heat that will readily melt gold, silver, or cast-iron." [1]

The above description of furnace is properly a *wind-furnace*, in which the temperature required for all the purposes to which it is applied, is obtained without the use of bellows, by means of a powerful draught, dependent on a narrow flue or chimney of considerable elevation. Fig. 1015 will give some idea of the small wind-furnace used by refiners and those who melt metal in pots. This furnace is shown connected with and projecting from the chimney: it should be of such a height as to allow the operator to look in to it on raising the cover or trap-door: it should be 12 or 15 inches square, and be furnished with movable bars: every part exposed to the fire should be formed of the most refractory bricks. When a very strong heat is required, the air should be conveyed by pipes from the exterior to the ash-pit. In the figure, a crucible is shown as placed in the furnace: the fuel used is coke, or a mixture of coke and charcoal.

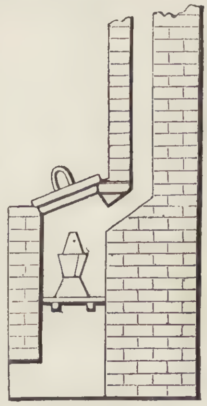


Fig. 1015.

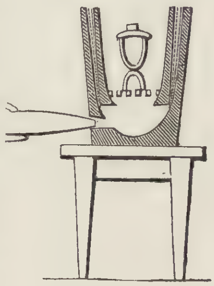


Fig. 1016.

The small *blast-furnace* represented in Fig. 1016 is described by Dr. Faraday from the one in the laboratory of the Royal Institution. The exterior consists of a blue pot, 18 inches high, and 13 inches in external diameter at the top. A small blue pot, $7\frac{1}{2}$ inches internal diameter, had the lower part cut off, so as to leave an aperture of 5 inches. This, when put into the larger pot, rested upon its lower external edge, the tops of the two being level. The interval between them, which gradually increased from the lower to the upper part, was filled with powdered glass-blowers' pots, moistened with water, and pressed down into a compact mass. A round grate was then dropped into the furnace, of such a size that it rested an inch above the lower edge of the inner pot: the space beneath it, therefore, formed the air-chamber, and the part above it the body of the furnace. The former is $7\frac{1}{2}$ inches from the grate to the bottom, and the latter $7\frac{1}{4}$ inches from the grate to the top. A horizontal conical hole, $1\frac{1}{2}$ inch in diameter on the exterior, was cut through the outer pot, forming an opening into the air-chamber at the lower part, for the purpose of receiving the nozzle of a pair of double bellows. The furnace must be perfectly dry before being used. The fuel is coke. The bellows are mounted on an iron frame, and the furnace is raised upon an iron stool, so as to bring the aperture of the air-chamber to a level with the nozzle of the bellows. This furnace is sufficiently powerful to melt pure iron in a crucible in twelve or fifteen minutes, the fire having been previously lighted. It will effect the fusion of rhodium, and even pieces of pure platinum have sunk together into one button in a crucible heated by it. All kinds of crucibles, including the Cornish and the Hessian, soften, fuse, and become frothy in it. Such a furnace as this should be used in the open air.

The *blast-furnace* used in making pig-iron will be described under IRON: for the *reverberatory* furnace, see COPPER, and some other articles relating to metallurgy: for the *assay* or *cupelling* furnace, see ASSAYING.

(1) Chemical Manipulation, Sect. I.

FUSEE. See HOROLOGY.

FUSIBILITY. See HEAT—METALS.

FUSIBLE METAL. See ALLOY—BISMUTH.

FUSTIAN, a coarse, thick, tweeled cotton, similar in the mode of manufacture to velvet, and generally dyed of an olive, leaden, or other dark colour. Besides common fustian, (known as *pillow* or *pillaw*) *corduroy*, *velverett*, *velveteen*, and *thicksett*, used for men's apparel, belong to the same class of fabrics. See WEAVING.

FUSTIC, a dye-stuff, the *bois-jaune* of the French, is the wood of the *Morus tinctoria*, a large tree growing in Brazil, Jamaica, and most of the West Indian islands. A concentrated decoction of fustic, deposits, on cooling, a yellow crystalline matter named *morine*. 1 part of fustic boiled in 10 of water for 15 minutes, gives a yellow decoction, which gradually deposits morine. The decoction is inodorous, slightly astringent and bitter, and precipitates gelatine. With protochloride of tin, and with alum, it gives yellow precipitates; orange-coloured with acetate of lead; yellow-brown with acetate of copper, and dark olive with persulphate of iron. With sulphuric acid, it gives an orange-coloured precipitate, soluble in excess of the acid. It is reddened by nitric acid, and rendered paler by oxalic and by acetic acid. The yellow of fustic is said to produce several greens with indigo, with which it unites well.

By the new tariff, fustic is admitted into the United Kingdom free of duty.

FUZE. See MINE—QUARRY.

GAGE, or GAUGE, an apparatus for measuring the state of a phenomenon; as the *air-pump gage*, which points out the degree of exhaustion in the receiver, [see AIR, p. 29,] the *wind-gage*, [see ANEMOMETER,] &c. There are also various gages used in particular trades and manufactures, such as those for measuring wires and sheet metals: these are usually thick plates of steel, of several sizes and forms, around and near the edges of which are drilled various holes, with notches sawed from the edge into every hole, saws of the widths of the several notches being used for the purpose. Small parallel plates of hardened and tempered steel, called *drifts*, are then driven into the notches, in order to smooth the sides, and render them of uniform width. The gage used at Birmingham for iron wire, and for sheet-iron and steel, differs from the gage used for sheet-brass, gold, silver, &c.; and both these differ from the Lancashire gage for round steel wire. These gages appear to have come into use "without any attempt at system, either as regards the values of the intervals between the successive measures or numbers, or their correspondence with the subdivisions of the inch." [1] Besides this, gages nominally the same are made by different manufacturers without a sufficient agreement as to the unity of measure. Messrs. Stubs, of Warrington, who manufacture a large number of these gages, tested the drifts which they employ by means of a sliding gage, for reading off quantities to the $\frac{1}{1000}$th of an inch, by means of a vernier. The results of these admeasurements are stated in the following table. It must, however, be understood, that the three series of measures or gages bear no relation to each other: indeed, this will be sufficiently evident by comparing the number on one gage with the corresponding number on the other two gages: thus, No. 10 on the three gages is equal to ·134, ·024, and ·190, respectively.

VALUES OF GAGES FOR WIRE AND SHEET METALS IN GENERAL USE, EXPRESSED IN DECIMAL PARTS OF THE INCH.

SECTION I. Birmingham Gage for Iron Wire, and for Sheet-iron and Steel.		SECTION II. Birmingham Gage for Sheet Metals, Brass, Gold, Silver, &c.		SECTION III. Lancashire Gage for Round Steel Wire, and also for Pinion-wire. The smaller sizes distinguished by numbers; the larger by letters, and called the Letter Gage.					
Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
0000	·454	1	·004	80	·013	40	·096	A	·234
000	·425	2	·005	79	·014	39	·098	B	·238
00	·380	3	·008	78	·015	38	·100	C	·242
0	·340	4	·010	77	·016	37	·102	D	·246
1	·300	5	·012	76	·018	36	·105	E	·250
2	·284	6	·013	75	·012	35	·107	F	·257
3	·259	7	·015	74	·029	34	·109	G	·261
4	·238	8	·016	73	·023	33	·111	H	·266
5	·220	9	·019	72	·024	32	·115	I	·272
6	·203	10	·024	71	·026	31	·118	J	·277
7	·180	11	·029	70	·027	30	·125	K	·281
8	·165	12	·034	69	·029	29	·134	L	·290
9	·148	13	·036	68	·030	28	·138	M	·295
10	·134	14	·041	67	·031	27	·141	N	·302
11	·120	15	·047	66	·032	26	·143	O	·316
12	·109	16	·051	65	·033	25	·146	P	·323
13	·095	17	·057	64	·034	24	·148	Q	·332
14	·083	18	·061	63	·035	23	·150	R	·339
15	·072	19	·064	62	·036	22	·152	S	·348
16	·065	20	·067	61	·038	21	·157	T	·358
17	·058	21	·072	60	·039	20	·160	U	·368
18	·049	22	·074	59	·040	19	·164	V	·377
19	·042	23	·077	58	·041	18	·167	W	·386
20	·035	24	·082	57	·042	17	·169	X	·397
21	·032	25	·095	56	·044	16	·174	Y	·404
22	·028	26	·103	55	·050	15	·175	Z	·413
23	·025	27	·113	54	·055	14	·177	A 1	·420
24	·022	28	·120	53	·058	13	·180	B 1	·431
25	·020	29	·124	52	·060	12	·185	C 1	·443
26	·018	30	·126	51	·064	11	·189	D 1	·452
27	·016	31	·133	50	·067	10	·190	E 1	·462
28	·014	32	·143	49	·070	9	·191	F 1	·475
29	·013	33	·145	48	·073	8	·192	G 1	·484
30	·012	34	·148	47	·076	7	·195	H 1	·494
31	·010	35	·158	46	·078	6	·198		
32	·009	36	·167	45	·080	5	·201		
33	·008			44	·084	4	·204		
34	·007			43	·086	3	·209		
35	·005			42	·091	2	·219		
36	·004			41	·095	1	·227		

1. The first column of the table refers to the gage used for most kinds of wire, and hence called the *Wire gage;* the *Birmingham wire gage*, and the *Sheet iron gage*. This gage is the most common of the three kinds specified in the table; it is used for iron, brass, and other wires, black steel wire, sheet iron, sheet steel, &c., and also for some manufactured works, including screws for joiners' use. The largest notch in this gage, marked 0000, measures 454 thousandths of an inch, or rather more than $4\frac{1}{2}$ tenths of an inch: the smallest notch, marked 36, measures 4 thousandths, or $\frac{1}{250}$th part of an inch. Thus there are 40 terms in this gage; but there are in practice no less than 60 sizes of wire, intermediate ones being made. In some cases the sizes are retained while the numbers are altered; as in the wires drawn for the manufacture of needles. No. 1 of the needle wire

(1) In the appendix to the second volume of Holtzapffel's work on Turning and Mechanical Manipulation, will be found a valuable paper, (which has been our chief authority in the present article,) entitled, "On the Gages at present used for measuring the thicknesses of Sheet Metals and Wires; and Proposals for a New System of Gages, founded on the decimal subdivision of the Standard Inch."

corresponds with $18\frac{1}{2}$ of the Birmingham wire gage: No. 2 needle-wire with 19 of the gage; $2\frac{1}{2}$ with $19\frac{1}{2}$; 3 with 20; 4 with 21; 5 with 22, and so on up to No. 21 needle wire, which agrees with 38 of the gage. In some cases half sizes of both series are interpolated, and the needles when manufactured are designated by another series of numbers, which bear no relation to either of these wire sizes. So also in the wire used for the strings of piano fortes, the sizes are known as Nos. 6 to 20, which agree very nearly with the sizes and half sizes of some of the notches of the Birmingham wire gages: thus the

Music wires, Nos.	6,	7,	8,	9,	10,	11,	12,	14,	16,	18,	20,
and Birmingham gage, Nos.	26,	$25\frac{1}{2}$,	25,	$24\frac{1}{2}$,	24,	$23\frac{1}{2}$,	23,	22,	21,	20,	19,

are respectively alike. The thinnest music wire, No. 6, measures about $\frac{1}{55}$th inch in diameter; and No. 20, the thickest, about $\frac{1}{25}$th inch. Pianofortes are strung much heavier than formerly, so that Nos. 1 to 5 have fallen into disuse. Steel wire is now used instead of brass. The covered strings are also of steel, with a fine copper wire wound spirally upon them.

2. The second gage in the table is the *Birmingham metal gage*, or simply the *metal gage* or the *plate gage* to distinguish it from the *wire gage*. It is used for most of the sheet metals, (except iron and steel,) viz. copper, brass, gilding metal, gold, silver, platinum, &c. The intervals in this gage are closer or smaller than those of the wire gage. Thus No. 1 is 4 thousandths or the 250th part of an inch wide, while the largest notch, No. 36, measures 167 thousandths, or very nearly $\frac{1}{6}$th inch. When thicker metals are wanted, their measures are sought in the wire gage: thus No. 36 on the plate gage nearly agrees with No. 8 on the wire gage, and the numbers 7, 6, 5, to 0000 of the latter are employed for thicker metals than can be measured by the plate gage. The plate gage often ends at 24, which agrees with 14 of the wire gage, and then the numbers 13, 12, 11 to 000 of the latter are used for thicker metals.

The method of describing sheet metals in commerce is liable to much variation. Thus

Sheet zinc, Nos.	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16,
and Plate gage, Nos.	4,	$4\frac{1}{2}$,	5,	6,	7,	8,	9,	10,	11,	12,	13,

are nearly alike. These thin sheets of zinc measure from $\frac{1}{100}$th to about $\frac{4}{100}$ths inch thick, and are used chiefly for gutters, roofs, and small works. Thicker plates from about $\frac{5}{100}$ths to $\frac{18}{100}$ths thick, used for zincography, door plates and engraved works, are commonly made to the notches 18 to 7 of the wire gage.

When the value of the metal in sheet exceeds the value of the labour afterwards expended on it, such metal is estimated by the weight of every superficial foot. Thus, cast and milled lead are described as of from 4 to 12 lbs. the superficial foot, the variation being 1 lb. to the foot. Coppersmiths and braziers do not use the plate gage, but reckon their metal as from about 3 to 56 lbs. to the sheet of 2 feet by 4 feet. The precious metals are sometimes estimated by the number of ounces or pennyweights troy to the superficial foot.

3. The gages entered under section 3 of the table, are used for the bright steel wire prepared in Lancashire, and the steel pinion wire for watch and clock makers.

Many other gages are used in particular trades, such as the *rod iron gage*, the *nail rod gage*, the *button makers' gage;* others used in *watch work;* there is also the gage used by *gun makers* for the bores of guns and rifles.

The above mentioned gages are all arbitrary, having no reference to a fixed standard; so that regarding the various gages as a system, it is one of confusion instead of order and method as it ought to be. The simple and inexpensive remedy for this state of things, proposed by Mr. Holtzapffel, is to employ the decimal divisions of the inch, and those under their true appellations. "Thus for most purposes the division of the inch into 100 parts would be sufficiently minute, and the measures 1, 2, 5, 10, 15 or 100 hundredths would be also sufficiently impressive to the mind: their quantities might be written down as 1, 2, 5, 10, 15 or 100 hundredths, as the decimal mode of expression might if preferred be safely abandoned, and the method would be abundantly distinct for common use if the word *hundredths* were stamped upon the gage, to show that its numerals denoted hundredths of an inch, quantities which could be easily verified by all. It does not follow that the entire 100 notches should be at all times used, as in many cases it might suffice that below 20 hundredths every size should be employed; from 20 to 50 hundredths, every alternate size: from 50 to 100 hundredths, every fifth size. As at present also, the upper or lower part of the series of terms might be omitted to any desired extent in those cases where they were beyond the particular wants of the artisan or the particular branch of trade, in order to diminish the bulk and expense of the gage. It may be objected to this scheme that for the more valuable metals and the more minute purposes, the quantity of the one hundredth of an inch is too coarse a difference. Two facile modes of remedy may be here applied. The first, to make half sizes: thus $8\frac{1}{2}$ or 8·5 would of course denote the medial interval between 8 and 9 hundredths. Or, secondly and preferably, below one tenth of an inch, a finer scale might be substituted for the more minute and delicate purposes, namely a gage based, in precisely the same manner, on the *thousandth* of the inch as the unit which would give a much finer degree of subdivision than is afforded by any of the gages in general use; in this case the intervals being derived from the thousandth of an inch, the word *thousandths* should be stamped on every such gage."

For the advantages and applications of this method, we must refer to Mr. Holtzapffel's work, as also to a pamphlet published by him, "On a New System of Scales of Equal Parts."

GAGING, or GAUGING, is the method of determining by actual measurement the number of gallons contained in vessels intended to hold goods. These vessels are either of simple and regular figure, as in

some casks which may be considered as the frusta of spheroids; or so irregular, that the content can only be found by dividing them into a considerable number of sections, and considering each section as a small cylinder or frustum of a cone. A writer in the Penny Cyclopædia, article Gauging, remarks on the old treatises on this subject, "The rules laid down were, in many cases, of uncertain application; as for instance, a close cask was to be treated either as a frustum of a spheroid or of a parabolic spindle, or as a double frustum of a paraboloid, or else of a double cone, according to its appearance. The allowance made for the thickness of a cask was a guess, and the method of using *small* sliding rules, to which supervisors formerly resorted to escape calculation, is a species of estimation which would never have been tolerated in money transactions between man and man. The inference to be drawn from the art, as described by early writers, is that, generally speaking, the results of excisemen's measurements were below the truth. . . . With *larger* sliding scales for calculation, and the aid of habit derived from experience, it is possible very accurately and easily to measure casks which do not depart much from a given standard of form. This is what is done by gaugers at the present time, and their practice has attained considerable accuracy. In a particular instance which has come to our knowledge, and in the case of a vat which held 6,500 gallons, the measurement of the exciseman did not differ more than ten gallons from the truth. This degree of accuracy is entirely modern, and must in a considerable degree arise from similarity of form being very nearly preserved in the different species of casks."

The most popular work on this subject was for a long time "The Practical Gager," by William Symons, compiled for the use of Excise officers. Warde's "Mathematician's Guide," and Hutton's and Bonnycastle's "Mensuration," contain small treatises on the subject.

GALBANUM, a species of gum-resin obtained from a perennial and apparently an umbelliferous plant growing in Africa, Syria, and Persia. It is imported chiefly from the Levant, in chests or cases of from one to three hundred pounds' weight. The best galbanum is in masses of whitish tears, agglutinated together, and having a strong balsamic odour: these are supposed to be the spontaneous exudation of the plant. The second sort is in dark irregular masses of inferior quality. Persian galbanum is very soft and tenacious, and is sometimes sent in skins. It often contains stalks and portions of the plant. Galbanum is used in medicine, as an antispasmodic, and is often associated with assafœtida, to which it possesses similar but inferior properties. Galbanum contains about 60 per cent. of resin, ($C_{40}H_{27}O_7$,) and 20 of gum, and yields, when distilled with water, a volatile oil, colourless and limpid, and having the odour of camphor.

GALENA. See LEAD.

GALL, or OX-GALL. See BILE.

GALLIC ACID, an acid obtained from nut-galls, [see GALLS,] which are to be powdered, mixed with water, and exposed for some weeks to the air at a temperature of 70° or 75°, water being added occasionally, to supply the loss from evaporation. During this time the powder swells and becomes mouldy. The mass, on being subjected to pressure, yields a quantity of coloured liquid: the cake which is left is then boiled in water, and the solution filtered while hot: on cooling, it deposits crystals of gallic acid, which may be purified by re-dissolving, and boiling with a small portion of animal charcoal. The filtered solution then deposits the gallic acid, in the form of white silky crystals. There are other methods of forming gallic acid, for which we must refer to chemical works. Gallic acid has a slightly sour astringent taste: it is soluble in about 100 parts of cold, and in 3 of boiling water: it is readily soluble in alcohol, and sparingly so in ether: it occasions no precipitate with gelatine. The formula for crystallized gallic acid is $C_7H_3O_5 + HO$. Heated to 212°, it loses 1 equivalent of water. This acid forms a number of salts called *gallates*. See TANNIC ACID—TANNINE—LEATHER.

GALLIPOLI OIL, a coarse olive oil imported from Gallipoli, a sea-port of the province of Otranto, in the kingdom of Naples.

GALLON, an old English measure of capacity. Until the year 1825 distinct gallons for wine, ale and beer, corn and dry goods, continued in use: thus the old wine gallon contained 231 cubic inches; the old corn gallon 268·6 cubic inches; the old ale gallon 282 cubic inches. The imperial gallon, as settled by the Act of 5 Geo. IV. cap. 74, contains 10 lbs. avoirdupois of distilled water, of which it is declared that 252·458 grains fill a cubic inch: consequently, the imperial gallon contains 277·274 cubic inches.

GALLS. GALL NUTS. The names given to hard, woody excrescences which form upon the shoots

Fig. 1017. GALL-NUTS.

and branches of a diminutive species of oak, *Quercus infectoria*, common throughout Asia Minor, from the Bosphorus to Syria, and from the shores of the Archi-

pelago to Persia. These galls are produced by the punctures of an insect, *Cynips gallæ tinctoriæ*, which deposits its eggs in the vegetable tissue, and thereby causes the shoot or bud to swell, and become an excrescence or gall within which the larva is developed. When the insect is perfect, it eats its way out, and the gall has then lost much of its value. The best galls, known in commerce as *black* or *blue galls*, from their blueish tint, are gathered before the insect has escaped, and are of great importance as a source of black dye, and also as a material in the manufacture of writing-ink. The *white galls*, or those from which the insect has departed, answer the same purposes in an inferior degree: they are larger than the blue galls, but less heavy and astringent; their colour is a brownish or dingy yellow, and they are perforated with a small circular hole, through which the insect made its escape. It is not an uncommon fraud to dye the whitish gall-nuts blue to increase their value, but this is soon detected by the colour being deeper than is natural, and also by the deficiency of the galls in weight, and by their perforation.

In the cultivation of the crop, great care is taken by the orientals to gather the galls at the time when they have attained their full size and weight. Any delay at this period is very injurious, giving the insect time to undergo its final metamorphosis, and to pierce the shell. The Aga of the district levies a tax on the produce, and is therefore interested in its success. He causes the cultivators to traverse the hills and mountains frequently, at the time of harvest, and watch carefully the progress of the galls on the oaks, which grow freely in such situations. The gall-nut is very hard, generally round, and covered with knots, some of which are pointed. The size varies from that of a pea, to that of a nutmeg. Galls are without smell, but they have a disagreeably bitter taste, and a powerful astringent action. They were used in medicine in the time of Hippocrates, and are still so employed to a certain extent, though their most extensive use is in the arts and manufactures, and as a chemical test.

The best galls come from Aleppo and Smyrna. In 100 parts of Aleppo galls Sir H. Davy found gallic acid 6·2; tannin 26; gum and insoluble tannin 2·4; lime and other salts 2·4; woody fibre 63. The galls occasionally brought from India are not the produce of that country, but are carried thither from Persia by Arabian merchants. Galls have been largely imported for many years; but a less expensive substitute is now greatly in request. This consists of the cups of the acorns of another species of oak, (*Quercus ægilops*, or the Velani oak,) which are found to partake of the nature of the gall-nut. The acorns of this oak are short and thick, and the cups very broad, and closely beset with oblong scales. The cups are known in commerce as *valonia*, and form an important article of trade from Smyrna and its neighbourhood. A fruit called Myrobalans, and resembling in appearance dried plums, is much used by the Hindoos as a substitute for galls, the useful properties of which it appears to possess.

Gall insects are remarkable for the wonderful mechanism which enables them to puncture the different parts of plants. Whether they produce the berry-shaped excrescences known as oak-apples, or the tuft of reddish-brown hair which forms the gall of the rose, or the artichoke galls of the oak-bud, or the leafy gall of dyer's broom, or the rose-like clusters which give their name to the rose-willow, or the woolly balls on the hawthorn, or willow, or the currant-gall produced on the catkins of the oak,—the machinery employed is always the same, though the species of gall-insect varies in each example. This machinery consists of a needle contained in a sheath, and having remarkable powers of extension derived from the peculiar construction of the body of the insect; so much so, that the needle can be extended to twice the length of the insect itself, within which it is lodged in a bent form, following the curve of the body, and running from its base near the anus, along the back, making a turn at the breast, and then assuming the curve of the belly and appearing again near the point whence it had originated. This curious structure, which is common to the various members of the genus Cynips, has been closely examined and described by Réaumur.

Some Chinese galls, subjected to examination by Mr. Doubleday, are stated to have contained minute insects, belonging to the family of the aphidians. The galls, on being broken, were mostly found to contain a quantity of white, downy-looking matter, and numerous little rounded dark-brown substances, not bigger than grains of coarse sand. These black or brown atoms were the insects whose puncture had produced the gall, and the downy matter was their peculiar white secretion. From their desiccated condition, and long shaking about, the down had become detached, and most of the legs and antennæ were broken off. The nature of the shrub which produces these galls has not yet been ascertained.

GALVANISM. The most important applications of this beautiful science will be found under Electric Telegraph — Electro-Metallurgy — Electro-motive Machines.

GALVANISED IRON. See Amalgam—Electro-Metallurgy.

GAMBOGE. See Camboge.

GANGUE, the mineral substance which encloses or accompanies any metallic ore in the vein. Quartz, lamellar carbonate of lime, sulphate of baryta, sulphate and fluate of lime, are common gangues; but many other substances become such when they predominate in a vein. The word is pronounced *gang*: it is from the German *gang*, a vein or channel.

GARNET, a vitreous mineral of the cubic system, composed of three or four silicates—those of alumina, lime, iron, and manganese; the varieties of colour being due to their varying proportions and combinations. The best specimens are called *precious* or *noble garnets*: these are of a clear, deep red, and are cut quite thin on account of their depth of colour. They are chiefly brought from Pegu, and are of considerable value. A variety of this stone is supposed to have

been the *carbuncle* of the ancients, and identical also with the *hyacinth*. Common garnet is very abundant, and of various colours, but is rarely fine enough to be employed with good effect in jewellery. In some parts of Germany, garnets are so abundant as to be used as a flux to some iron ores. They are also pounded, and used as a substitute for emery.

Garnet is usually met with in the forms of dodecahedrons and trapezohedrons, but these may be variously modified. It is also found in granular masses. The sp. gr. varies from 3·35 to 4·24.

GAS, the generic name of all those elastic fluids which are permanent at low temperatures. In this respect they differ from vapours, which become liquid or solid on reducing the temperature. The difference, however, is only one of degree; for Faraday has succeeded in liquefying many of the gases, and solidifying a few of them, under the influence of cold and pressure. [See Carbonic Acid.] For the physical properties of gases, we must refer to Air. The most important gases are described under their respective names.

GAS-LIGHTING. An inflammable air, capable of affording light and heat, is formed naturally in many parts of the world. At Baku, on the shores of the Caspian Sea, the "holy fires," as they are called, are produced by the combustion of gas which issues from the earth. The burning fountain of Dauphiné is of similar origin: in Italy, Hungary, Greece, England, America, and China, natural springs of gas occur. In China these natural gasometers are profitably applied in boiling and evaporating the salt brine obtained by boring; other tubes convey supplies of the gas for lighting streets and houses, and the excess is got rid of by burning in a chimney beyond the limits of the salt-works. At the time we are writing (December 1851) the newspapers contain an account of a large blaze of natural gas on Chat Moss, on the line of railway between Manchester and Liverpool. The gas was liberated in boring for water: the first 16 feet being through moss and peat, and the next 16 feet through marl: then followed 2 or 3 feet of sand; and while scooping through this portion the gas suddenly appeared, with a loudish noise and a slight sulphurous smell. A stream of gas then floated along the surface of the ground, which took fire on the application of a light. A pipe, 10 or 12 inches in circumference, was then inserted into the ground to the depth of 2 or 3 feet, and with a height of about 36 feet, by which means the gas was conveyed above the level of the neighbouring forest trees: it burnt at the top of the tube with a flame apparently 8 or 9 feet long: its colour was yellowish mingled with blue tints: the light was strong enough to allow a person at the distance of 100 yards to see the time by his watch. On applying the ear to the pipe, the sound of the gas traversing it could be heard like the sound of rushing water. The flame has since been extinguished by the wind.

This gas is probably the *light carburetted hydrogen* of chemists (CH_2), the *fire-damp* of the coal-pit, and also known as *marsh-gas*, from the circumstance of its being found abundantly in stagnant pools during the spontaneous decomposition of vegetable matter. So long since as the year 1659, Thomas Shirley attributed the exhalations from the burning well of Wigan in Lancashire to the subjacent coal-beds; and a few years later Dr. Clayton, Rector of Crofton, at Wakefield in Yorkshire, actually prepared gas by the distillation of coal, washed it in water, collected it in bladders, and burnt it from a jet. And yet, notwithstanding this suggestive experiment, which was communicated to the Royal Society, considerably more than a century elapsed before gas-lighting took its place among the industrial arts. In 1770 a spontaneous evolution of gas took place at a colliery near Whitehaven, which was kindled, and burned with a flame more than 2 yards long. This was noticed in the Philosophical Transactions for 1773, about which time Dr. Hales and also Dr. Watson obtained gas by the distillation of coal. In 1786 Lord Dundonald erected coke furnaces and burned the gases in tubes for the amusement of his friends, but apparently without any other object. In 1792 Mr. Murdock employed coal-gas for lighting his house and offices at Redruth in Cornwall; and in 1802, on the occasion of a general illumination, he lighted up part of the Soho manufactory near Birmingham, belonging to Boulton and Watt, with a display of gas-lights. In 1804 and 1805 the same gentleman lighted with gas the cotton-mills of Messrs. Philips and Lee at Manchester, and distributed a quantity of light over the building equal to nearly 3,000 candles. This was the first extensive application of coal-gas to the purposes of illumination, and it soon became general. About this time Mr. Winsor went about giving lectures on the subject, and gradually overcame the ridicule and incredulity which were opposed to his plan of lighting a whole city with gas. In 1812 a part of London was lighted in this way; and in 1815 the method was introduced into Paris. About the year 1804 Mr. Samuel Clegg began to devote his attention to the subject, and he afterwards rose to eminence as a gas engineer.

The light carburetted hydrogen above alluded to is a gaseous compound of carbon and hydrogen, 100 parts by weight containing 75 of carbon and 25 of hydrogen. The illuminating power of this gas is far inferior to that of another compound of these two elements, called *bicarburetted hydrogen*, or *olefiant gas;* it contains twice as much carbon as the former gas in the same bulk. Olefiant gas does not occur naturally: it is obtained by the destructive distillation of oil; and it is also obtained together with light carburetted hydrogen and other substances more or less luminous, when coal, resin, tar, asphaltum, fat, animal refuse, and similar inflammable matters, are distilled for the purpose of obtaining gas for artificial illumination.

In this country gas is usually produced from coal, which must be bituminous in quality: cannel coal produces good gas in large quantity; next to this is Scotch parrot coal. By a rough estimate, 100 cubic feet of coal yield from 18,700 to 9,200 cubic feet of gas, according as the best kinds of Scotch or Lancashire coal are used, or the worst kinds of Staffordshire coal.

But perhaps the richest gas-making coal in the world (if *coal* it may be called) is that known by the name of *Boghead cannel.* It is stated by the proprietors, in their advertisement for the sale of this article, that "it is the most highly bituminous coal known, and therefore well adapted for mixing with inferior coals in the manufacture of gas. It yields 13,500 cubic feet of gas, of the sp. gr. ·775, per ton; and a burner consuming at the rate of 1 cubic foot per hour gives a light equal to $8\frac{1}{2}$ spermaceti candles, each consuming 120 grains of sperm per hour." This so-called cannel coal is a variety of clay or shale saturated with bitumen. Its mean specific gravity is 1·247; it is hard and tough, and when broken shows a conchoidal fracture; the colour varies from blackish grey to brown; the surface appears earthy, and has no lustre; a chip of it takes fire by holding it for a moment in the flame of a candle, and burns easily. When heated below redness in a glass retort, it yields combustible gases, as well as a large amount of volatile combustible liquids, holding in solution much solid combustible matter.[1] No ammonia is produced during the distillation. There is left in the retort after all volatile matter has been expelled, a black mass, which, when heated in the open air, is found to consist of earthy ingredients, principally silicate of alumina, the remainder being carbon. The mean of three analyses of this coal gave, volatile matter 68·12, ashes 27·75, carbon 4·13. Boghead is situated about half-way between Edinburgh and Glasgow, and the coal occurs close to the large village of Bathgate, which is increasing in prosperity owing to its discovery. It is exported largely from various ports of the Frith of Forth to England, the Continent, and even to South America.

The production of the gas depends upon the application of a high temperature to the coal. At a moderate heat, such as 400° Fahr., the volatile constituents of the coal pass off in the state of fluid hydrocarbons or naphtha, with little or no admixture of permanent gas. At a cherry-red heat, or a little higher, there is an abundant production of gas, with only a small production of tar and naphtha.

The coals must not be wet, or when suddenly exposed to a red-heat the outer portions will become coked long before the water in the centre of the coal is expelled: consequently, as the heat penetrates the coal, this water is converted into steam and driven over the red-hot coke, thus leading to the production of hydrogen, carbonic oxide, and carbonic acid, the first two of which dilute the gas and lower its illuminating power,[2] while the third only serves to neutralize the lime when the gas is passed through the purifier. The conversion of the water into steam by the absorption of sensible heat, lowers the temperature towards the point more favourable for the production of tar or naphtha than of gas. At too high a temperature, on the contrary, the rich olefiant gas is decomposed into light carburetted hydrogen and carbon, the latter often lining the gas-retort in distinct layers, an inch or more in thickness. The iron pyrites of the coal forms, at a low red-heat, protosulphuret of iron and free sulphur; and the latter, uniting with the hydrogen of the coal, forms sulphuretted hydrogen. The nitrogen of the coal uniting with a portion of its hydrogen forms ammonia. Hence it will be seen that the distillation of coal leads to complicated results.

The coal is distilled in tubes of cast-iron, called *retorts;* they are usually about 7 feet long, and 1 foot in diameter. Before being used they are tested by being placed in water, and then forcing air through them: if any flaw exist it is detected by the air escaping in bubbles. Each retort is usually in two pieces, which are connected by flanges and screws; namely, the *neck,* or *mouth-piece,* and the *body,* or hinder part, which by constant exposure to the fire soon wears out and requires renewal, while the mouth-piece is but little acted on. The retort is charged and discharged at the mouth, which is closed by a lid, and fixed by means of a screw and a holdfast, Fig. 1018; the joint being made tight by a luting of clay or refuse lime from the purifier. The

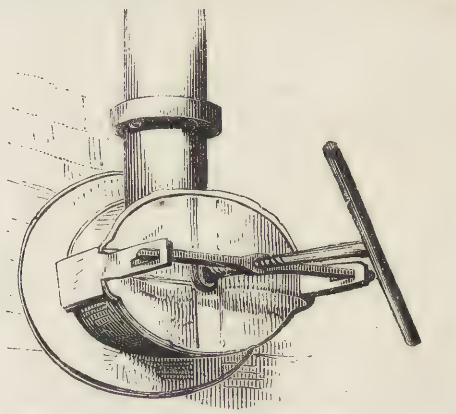


Fig. 1018. MOUTH OF THE RETORT, SHOWING THE METHOD OF CLOSING.

gases which are generated from the coal escape from the retort by a wide tube cast into the mouth-piece, and shown in Fig. 1018 rising up therefrom. The best form for the body of the retort, for obtaining the largest quantity of gas in the shortest time, was long a matter of discussion. The first retorts used on the general introduction of the system were in the form of a circular tube, Fig. 1019, *a,* a form still used

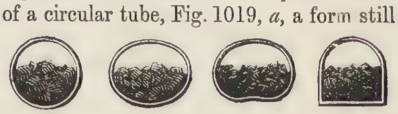


Fig. 1019.

with cannel coal: these were for the most part superseded by the elliptical form, *b,* which was further improved by bending in the lower surface into a *kidney-shape,* as at *c,* whereby a much larger portion of the charge is brought into contact with the red-hot sides than in the other forms. The breadth of kidney-shaped retorts is usually from 20 to 22 inches, and

(1) This substance is chiefly used by Mr. Young, in the distillation of paraffine and mineral oil. See *Introductory Essay,* p. lxxxiii.

(2) Attempts are now being made to turn this process to useful account in the production of what is called *water-gas,* as will be noticed further on.

the height in the middle from 9 to 12 inches. In all three forms, with the same length of 6½ feet exposed to the fire, 150 lbs. of coal, only half-filling the retort, will cover in the round form a red-hot surface of 10 inches in width; in the oval form, a surface of nearly 12 inches, while the charge is much nearer the top of the retort than in the circular form. It is stated that this variation in form has reduced the time required for heating one-half; that the average quantity of gas obtained from a ton of Newcastle coal in the elliptical or the kidney-shaped retort is 9,000 cubic feet; while in the circular retort only 6,400 feet have been obtained. D-shaped retorts, Fig. 1019, *d*, are also in common use.

The retorts are heated in furnaces; 5 retorts being usually arranged in one furnace, two and two, and one above; and each furnace has two separate fires, the brickwork being so arranged as to divide and distribute the flame among the retorts, coke and coal being the fuel. At most works the furnaces are arranged in rows on each side of the retort-house, their flues meeting in a central chimney. In extensive gas-works there are from 400 to 600 retorts, of which from 200 to 300 are worked on the average of summer and winter, each retort being charged with about 120 lbs. of coal every 6 hours. Two men attend to 3 furnaces of 5 retorts each, and as the retorts are kept constantly at work, the men work in shifts of 12 hours at a time, with intervals for rest and meals: they are not actually engaged at work more than half that time. The tubes which rise from the retorts R R, Fig. 1022, are recurved at the top, and dip into a large horizontal tube H, called the *hydraulic main*.

The improved scientific knowledge of the gas-maker enables him to arrange a much larger number of retorts in one furnace. At the Great Central Gas-works, Bow Common, under the intelligent management of Mr. Croll, no less than 13 retorts are heated by one furnace-fire. They are disposed in the manner shown in Fig. 1020: the furnace-fire is placed in a central position; the upper series of 6 retorts are heated by the radiation of the fire; the other 7 retorts are heated by the hot draught descending in the direction of the arrows. These retorts are each 18 feet in length from the face of the brickwork setting, and they are charged and discharged at both ends. The upper series of retorts are made of fire-clay; 4 of which are circular, and 2 oval in shape, with circular iron mouth-pieces. The lower series of retorts are of iron; each retort with its mouth-piece being formed in one casting, 19 feet 6 inches long. The clay retorts will bear a stronger heat than the iron ones, and being situated in the same arch with the furnace, are exposed to a much greater heat, which admits of their being charged every 4 hours; the iron ones are charged every 6 hours. The average yield of gas per day at these works, from each double retort, 18 feet in length, is 8,500 cubic feet. Retorts made of fire-clay retain their heat at nearly the standard temperature when a fresh charge of coal is introduced, and their superior durability compared with iron retorts compensates for the slight increase of fuel which they require. It is difficult to maintain iron retorts at a uniform high temperature, and to prevent their being burnt out faster in one part than in another, especially in the old arrangement, where the furnace-fire is large, and the retorts are few in number, and far asunder. In the new arrangement one cannot help being struck with the large number of retorts in a small space, whereby a great saving is effected in the

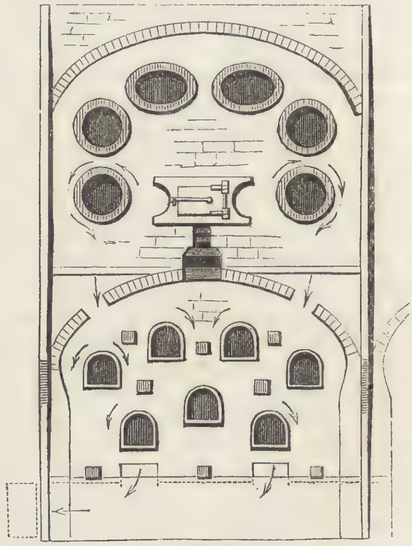


Fig. 1020. ARRANGEMENT OF THE RETORTS.
(*Front elevation, exterior.*)

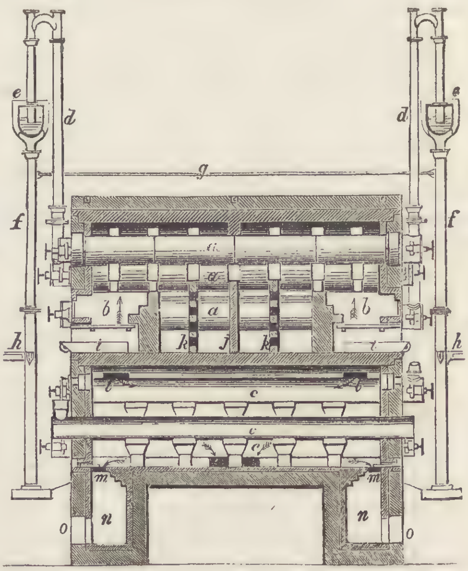


Fig. 1021. ARRANGEMENT OF THE RETORTS.
(*Side elevation, in section.*)

superficial space required for the retort-house: there is also a great economy of fuel; one ton of coals in the retorts being carbonized with only 12 to 15 per cent. of fuel, as compared with 25 to 35 per cent. in ordinary practice. The iron retorts also last longer, the flame being more generally diffused by the downward draught. The carbonaceous incrustation can

also be much more easily removed from the interior of the retorts, in consequence of their being open at each end. The usual make of gas at these works is 900,000 cubic feet per day, to produce which twelve settings are in use. These occupy an area of 18 feet in width by 124 feet in length, and are capable of producing 1,200,000 feet a day. The retorts reach from end to end of the setting, being more than double the ordinary length, and they are fired and charged from each end. In Fig. 1021, *a a* are the clay retorts, arranged round the furnaces *b b*, and exposed to the immediate contact of the flame; *c c* are the cast-iron retorts, arranged beneath the furnace, and heated by the current of hot air, which in descending diffuses itself equally over the lower set of retorts. Hence, while the clay retorts are exposed to the fiercest heat of the furnace, the cast-iron retorts encounter a milder temperature, suited to their superior conducting power; and hence, instead of discharging flame and intensely heated air into the chimney, as is done by the old method, the arrangement of the retorts and the descending draught leads to the economy of fuel already noticed. The close setting of the retorts does not allow all the pipes *d d* to ascend from one end into the hydraulic main; they are therefore carried off some at one end and some at the other, and descend into the two hydraulic mains *e e*. These mains are cast in lengths equal to the distance between the centres of the sets of retorts, and are carried by the hollow columns *ff*, which are tied together across the retort setting by tie-rods, *g*. These columns also serve to carry the girders *h h*, and the cast-iron platform upon which the upper retorts are worked. The space below this platform (Fig. 1024) is used in working the iron retorts, as well as for receiving the coke from the clay retorts; sufficient space being left between the edge of the platform and the brickwork to allow the coke from the upper retorts to fall down into the coke *omnibuses*, in order to be conveyed to the coke heap. Wrought-iron water-troughs, *i i*, are used, to keep the fire-bars cool: there is only one fire-bar to each furnace, and this is of round iron for the easier separation of the clinker. A partition-wall *j* extends completely across the arch, to divide the two furnaces, and thus prevent one furnace drawing into the other. The walls *k k* serve to carry the retorts, and are perforated with holes for the passage of the draught. The spaces *l l* in the lower arch form the communication between the upper and lower settings; the draught, after surrounding the lower retorts, passing through the openings *m m* into horizontal flues *n n*, which run the whole length of the retort settings, and communicate with the main flue which enters the chimney. Dampers formed of fire-tile slide over the openings *m m*, to adjust the draught, and flue-doors *o o* are provided for cleaning out the flues *n n*.[1]

Now supposing the retorts to be at a bright-red heat, and just charged, the first action of the heat is to expel the atmospheric air from the retorts, and moisture from the coals. As the coal becomes hot a considerable quantity of tar distils over into the hydraulic main, together with a portion of gas consisting chiefly of hydrogen and ammonia. The gas constantly increases in quantity; tar and ammoniacal liquor pour over together, with a portion of sulphurous acid from the pyrites of the coal. The gases are most abundantly disengaged when the retorts are kept at a bright cherry-red heat: it has been computed, that in 8 hours' distillation with a uniform fire and the retorts at a constant red heat, the relative quantities of gas given off, on a per centage of the whole charge, are in the first hour 20, in the second 15, in the third 14, in the fourth nearly 13, in the fifth 12, in the sixth 10, in the seventh 9, and in the eighth about 8. At these different periods, however, the qualities of the gaseous products are very different: the gas which comes off before the retorts have acquired their proper temperature burns with a feeble light; the best gas is given off when the retort has just acquired a vivid-red heat, for the gas then consists chiefly of carburetted hydrogen and olefiant gas, 100 measures of the gaseous products containing 82·5 of carburetted hydrogen, 13 of olefiant gas, 3·2 of carbonic oxide, and 1·3 of nitrogen. By continuing the distillation the valuable gases diminish in quantity; and those which burn with little or no light, such as hydrogen, sulphuretted hydrogen, and carbonic oxide, and those which do not burn at all, but extinguish flame, such as nitrogen and carbonic acid, increase in proportion.

The tar which distils over into the hydraulic main, covers the mouths of the conducting tubes, as shown in Fig. 1022, by which means the retorts are prevented from communicating with each other, so that any one may be opened and charged without interfering with the others. The tar is prevented from accumulating in the hydraulic main by means of a syphon tube, so arranged as to carry it off into the tar-cistern as it rises above half the horizontal section of the main; but by turning a cock at one extremity of the main all the tar can be drawn off.

When the distillation of the coal is carried as far as it is thought desirable, the lid of each retort is loosened, and the gas ignited at the mouth: if the lid were at once removed, the air rushing in might form an explosive mixture with the gas in the retort, and thus lead to accident. When the lid is removed, the remainder of the gas burns out at the mouth; the glowing coke is then raked out into an iron carriage, called a *coke omnibus*, moving on a line of railway in front of the furnaces. As soon as the coke falls into the carriage, water is dashed upon it to quench it. The retort is then cleared out by means of hoes or scrapers with very long handles, the retort all the time retaining its cherry-red heat. A long auger is also passed up the pipe leading into the hydraulic main, to clear away condensed tar, which if allowed to remain would prevent the distillation from going on. Each retort is recharged by means of a long curved tray of sheet-iron, Fig. 1023, called a *scoop;* this is filled with coal and pushed to the end of the

(1) In *The Artizan* for April 1851, and some of the subsequent numbers, will be found a detailed description of the Great Central Gas-works, together with a history of the formation and operations of the Company.

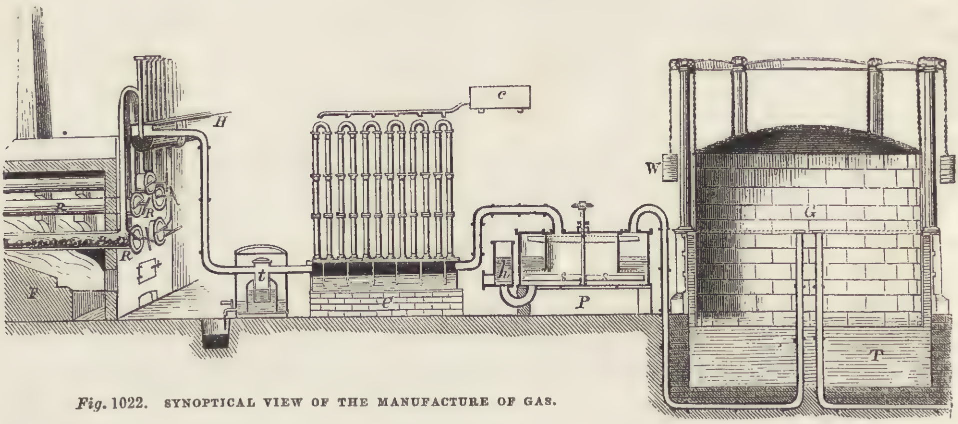


Fig. 1022. SYNOPTICAL VIEW OF THE MANUFACTURE OF GAS.

retort, inverted so as to turn out the coal, and then withdrawn. A portion of the coal is immediately

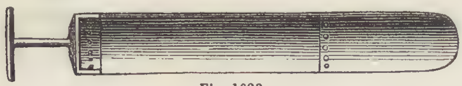


Fig. 1023

converted into gas, which pours out at the mouth in a copious flame; but this is soon checked by the cover, previously luted, which is quickly screwed on.

Fig 1024. THE RETORT-HOUSE. (*Great Central Gas-works.*)

and the distillation proceeds as before. "This discharging and recharging of the retorts is a very hot and laborious duty, and has a remarkably picturesque effect, especially during the quiet of a clear calm night: the glowing heat of the furnaces, the bursting flames of gas when the retorts are opened, the rush of black smoke and flame which accompanies the fresh charge, the workmen with their long rakes and shovels, the shadows of their naked bodies appearing dark-green upon a red ground; the striking effects of light and shade; the noise, the exertion, the turmoil, the suffocating heat and odour alike oppressive,—all this is in striking contrast with the refreshing coolness and calmness of the sky seen through the openings of the gas-house. The effect is perhaps equally striking, although in another way, on a bright day, when the beams of sunshine penetrating the gloomy retort-house through chinks in the roof, are so loaded with smoke, and steam, and dust, as actually to appear like solid masses of matter. When the retorts are charged, and the fresh coke has been wheeled away to the heap, the noise, the dazzling bursts of flame and much of the heat, subside into a more quiet and sober scene, but still the heat and the loaded atmosphere of the place are oppressive, and the writer has always felt more relief in quitting a gas-house than any other factory which it has been his pleasant duty and privilege to visit in preparing these treatises for the press."[1]

Most of the tar and ammonia of the coal condense in the hydraulic main and are disposed of in the tar cistern: the hot gas, which also passes into the main, holds in suspension a considerable portion of the vapour of these substances, which must be immediately got rid of, or they would in cooling condense in the distant parts of the apparatus, and stop up the pipes. The hot gas is therefore made to pass from the hydraulic main to the coolers or condensers, a common form of which consists of a number of upright tubes, encased in larger ones containing water, which is kept cold by constantly flowing in at the bottom, and being heated by the tubes through which the hot gas is circulating, escapes in a stream at the top. Another form, shown at Fig. 1022, is the *air*-condenser, in which the enclosing tubes of water are dispensed with, and the cooling is assisted by cold water from the cistern

(1) Tomlinson's Useful Arts and Manufactures of Great Britain Vol. ii.

C, trickling down over the tubes: but in this case a larger amount of cooling surface is required, which is provided by 20 or 30 lofty tubes. The gas in passing through these cooled tubes is considerably reduced in temperature, and the vapour of tar, &c. condenses into a liquid, which trickles down into the divisions of the iron chest at C, whence it flows back into *t*, and can be drawn off from time to time by the tap into a pit or sunk cistern. The gas enters the condenser at the temperature of about 120°, and leaves it at about 60°.

The gaseous and vaporous products of the distillation, by their elasticity consequent on their high temperature, force for themselves a passage from the retorts into the condenser, &c. This pressure, however, is objectionable, because should a retort be cracked or be badly secured, much of the gas would escape and be lost; or should any of the pipes become choked with tar, the increasing elasticity of the accumulating gas might lead to dangerous explosions. To avoid such inconveniences, an *exhauster*, consisting of a pumping apparatus, is at some works introduced between the condenser and the lime purifiers, the effect of which is to relieve the retorts from internal pressure by causing the gas to move through the condensers and propelling it forward to the lime purifiers.

The impurities which are got rid of by passing the gas through lime, are sulphuretted hydrogen and ammonia, the latter in combination with carbonic, muriatic, sulphuric and sulphurous acids. There are two kinds of purifiers, the wet and the dry. In the wet lime purifier, the gas on leaving the condenser passes through the inlet pipe A, Fig. 1025, into the chamber B, which, with the hoop D, forms a sort of inverted funnel, which is supported by the iron beams C. The outer vessel contains a mixture of lime and water, called *milk of lime.* The gas on entering depresses the lime-water in the funnel, and then escapes through numerous minute apertures into the liquid, where the bubbles are dashed about and brought into intimate contact with the lime by means of a stirrer, E *e*, revolving rapidly round on the spindle S, passing through a stuffing-box G, by wheel and

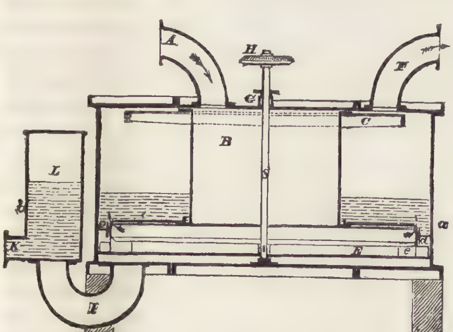


Fig. 1025. WET LIME PURIFIER.

pinion work H. As the lime-milk becomes saturated with the impurities of the gas, it is drawn off by a pipe I, and, by opening a slide-valve K, the lime-water can be completely drained off, without allowing the gas to escape with it. A fresh supply of lime-water is introduced by means of the cistern head L. F is the outlet pipe. The quantity of lime used must depend upon the per centage of sulphuretted hydrogen and carbonic acid in the gas. If, for example, there be 5 per cent. of these gases, about $1\frac{1}{2}$ lb. of lime will be required for every 100 cubic feet of gas. In some works three purifiers placed at different elevations are used in succession, the last of the series being the most elevated. From this the lime-water overflows into the second, and from the second into the first. By this means the gas is brought into contact with lime of gradually increasing purity, and is thereby more completely purified. The spent lime, which is of an excessively fetid odour, is not allowed by law to be thrown out as refuse; it is evaporated in the ash-pits of the furnaces, and then used as mortar for luting the retorts, &c.: it is also sold for mortar, for manure, and for the use of the wine-bottle glass-blower.

Dry lime, or, more properly, hydrate of lime, is now usually employed in the purification of gas. In the dry lime purifier, the gas is let in by the pipe A into the bottom of a rectangular iron vessel about 3

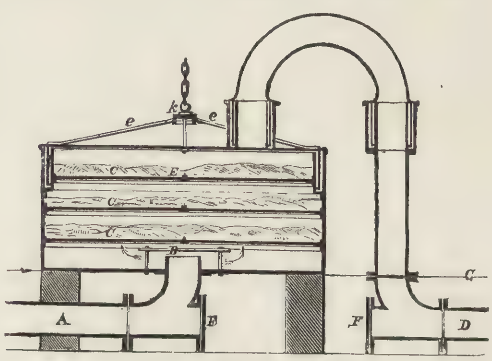


Fig. 1026. DRY LIME PURIFIER

feet deep: over the mouth of the inlet pipe is a plate of iron, B, to separate the gas, and prevent the lime from falling into the pipe. This vessel is in some cases divided into two compartments by a partition extending not quite to the top: the gas filters up through one compartment and down through the other, passing each way through several layers of lime, C C, placed on iron gratings, or perforated shelves of cast-iron, 7 or 8 inches apart. The perforations are each $\frac{3}{8}$ inch in diameter, and $\frac{3}{4}$ inch asunder. The purifier is covered with a light lid of sheet-iron. The lime being fresh slaked and slightly moistened, is placed on each shelf to the depth of about 3 inches, and then sprinkled with water from the rose of a watering pot. A bushel of quicklime is said to be sufficient for the purification of 10,000 cubic feet of gas. By slaking and reducing it to a proper consistency for use, its bulk becomes more than double; two bushels of the hydrate thus formed will cover a surface of 25 square feet, to a depth of $2\frac{1}{2}$ inches, this being the thickness which answers best. At some works a bushel of slaked lime, or half a bushel of unslaked lime, is allowed for every ton of coals that

is distilled. According to another estimate, 40 lbs. of lime are required for every 10,000 cubic feet of gas from Newcastle coal of average quality. If more lime be used the coal must have been damp, or have contained more than the usual average of sulphur. Good Newcastle coal contains about 1 per cent. by weight of sulphur; some kinds of cannel, only ½ per cent. The gas is usually passed through two, three, and even four dry lime purifiers, all constructed on the same principle. In Fig. 1026, D is the outlet pipe, leading to the second purifier G. The movable top or cover of each purifier fits into a water joint or trough, 10 inches deep and 6 inches broad. The shelves are also movable, the upper ones being taken out while the lower are being charged. The spent lime, which contains hydrosulphuret of ammonia, is very offensive, on account of its evolving sulphuretted hydrogen in contact with the atmosphere, the carbonic acid of which takes its place. This is entirely removed before the purifiers are emptied, by connecting each purifier by means of a joint with a large horizontal pipe which opens into the chimney-shaft of the retort house, the powerful draught of which rapidly exhausts the air from the horizontal pipe, and all the offensive volatile matters of the lime escape from it, as into a vacuum, and are speedily decomposed by the hot air of the chimney. After this, the cover of the lime purifier can be raised by means of the chain *k*, attached to the light rods *e e*, and the purifier be cleaned out without any annoyance to the men or to the neighbourhood. The lime thus removed is burnt in ovens, and used a second time in the purifiers, after which it becomes refuse. F F are blank flanches, which, when removed, allow the pipes to be cleaned out.

The lime removes from the gas carbonate of ammonia and carbonic acid about 2 per cent., and sulphuretted hydrogen about 1 per cent.; varying with the nature of the coal and its dryness. If the gas be properly purified, it ought to return good answers to the following tests:—turmeric paper moistened and held in a jet of the gas ought to retain its yellow colour; if the gas contain ammonia, the yellow will change to reddish brown; or blue litmus paper, slightly reddened by an acid, will have its colour restored; if there be no ammonia the red will remain. A paper dipped in a solution of acetate of lead, and held in the gas, will turn black if sulphuretted hydrogen be present; if the gas be made to pass in bubbles through lime-water, a milkiness will be produced if carbonic acid be present. It usually happens, however, that after the gas has passed through the lime purifiers, it still contains a little ammonia; this would be absorbed by the water of the meter, if it could be kept long enough in contact therewith. As this cannot be done, it is disposed of more quickly by passing the gas through a solution of alum or of green vitriol, or through dilute sulphuric acid: chloride of calcium, and other substances, are also used for the purpose. A water washing is, however, quite sufficient, if it be properly managed. At some works the gas from the purifier is conducted to the bottom of a tank called a *scrubber;* this is filled with coke for the purpose of greatly increasing the surface, and water being introduced at the top by a horizontal perforated tube, trickles slowly down over the coke, while the gas passes in the contrary direction. At some works this gas is mixed with steam, and being exposed to a low temperature, the steam is condensed in drops, whereby the gas is exposed to a considerable liquid surface.

The economic value of ammonia as a manure has led to attempts of late years to condense the whole of it in an unobjectionable form, so as to make it available. By Johnson's method the gas is purified by exposure to a compound of sulphate and biphosphate of lime, prepared by acting on burnt bones with sulphuric acid. This compound is disposed in trays in such a manner as to absorb the ammonia of the gas passed over it, thus forming a mixture of sulphate of ammonia and phosphate of lime, which is of course a valuable fertilizing material. By Laming's process, a solution of chloride of calcium, or muriate of lime, absorbed into saw-dust, is used, by which means the muriate of lime is gradually decomposed, and carbonate of lime and muriate of ammonia are formed, which are used as manure, or in the manufacture of sal ammoniac. Sulphate of lime, and various other earthy and metallic salts, such as the sulphates of magnesia, alumina, zinc, iron, and manganese, and chlorides of the same substances, have all been, or are now being used for the purification of coal-gas. At the Great Central Gas-works a solution of chloride of manganese is used. It is said to be effectual in purifying the gas from ammonia, and also absorbing a portion of the sulphuretted hydrogen, economising the lime to the extent of 30 per cent.

The use of the scrubber before the lime purifier, as is done at the Westminster works, leads to a considerable saving of lime, for there is an absorption of the ammonia, and the prevention of its reaction on the carbonic acid in the lime purifier, whereby carbonate and hydro-sulphate of ammonia are formed. Laming's plan can only be used before the gas passes into the lime purifiers.

Supposing the gas to be sufficiently purified, it is next passed through the station meter, which registers the quantity of gas made at any given hour of the day or night. This meter is similar in principle to the consumer's meter, hereafter to be described. Attached to it is a *tell-tale*, which serves the purpose of pointing out every irregularity in the production of the gas during the 24 hours. In the centre of the *dial-field* is fixed a circular plate, connected with a train of wheel-work, set in motion by an enclosed drum, through which the gas passes, indicating tens, hundreds, thousands, &c. of cubic feet of gas. Upon this circular plate is fixed a disc of paper, divided into 24 parts, with subdivisions. Suppose the meter to register 300,000 cubic feet in 24 hours, and the plate to be connected by wheels in the ratio of 3 to 1 to that index, which marks 100,000 in one revolution; it is evident that the distance travelled by one of the 24 divisions of the plate, from a certain fixed point, will indicate the quantity of gas made in

one hour, or $\frac{300,000}{24} = 12,500$ cubic feet. Above this divided disc is a time-piece, to the minute-hand of which is attached a detent, furnished with a pencil, pressing by a spring upon the disc. As the minute-hand of the time-piece revolves, the pencil, by means of a guide fixed to the meter-case, is regulated, so that in the first half-hour it will make a vertical line upon the paper, in length equal to the diameter of the circle formed by the minute-hand, measured from the

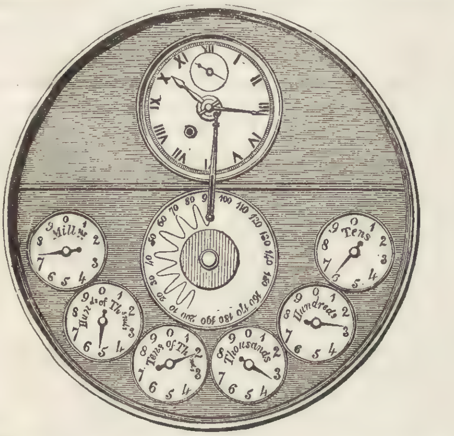


Fig. 1027. TELL-TALE ATTACHED TO THE STATION-METER.

centre to the point at which the detent is fixed; in the second half-hour the line will be retraced by the hand rising again. This arrangement supposes the divided disc to be stationary; but as it is made to revolve upon an axis which is also the axis of the internal drum, set in motion by the gas, the pencil will make a series of curved lines, meeting the divided circle of the disc every hour, and the distance travelled from point to point will mark the number of cubic feet of gas made during every hour of the 24. If the production of gas is regular, the figures formed by the pencil will be regular also; if, on the contrary, any neglect has occurred, the irregularity of the figure will detect it, and point out the hour and the amount of difference; because, if the speed of the revolving disc be decreased, the figure formed will approach nearer to the straight line; if increased, the points of intersection upon the divided circle will be further apart. The case of the station-meter is usually much ornamented, and has a Latin inscription.

The gas is next passed into the *gasometers*, or gas-holders, which form such conspicuous objects at gas-works. Each gas-holder is a cylinder, closed at the top, and floating, or suspended, with its open end in a cistern of water. The dimensions of the gas-holder are regulated by the geometrical law, that a cylinder has the greatest capacity with a given surface, when its height is equal to half its diameter; hence the capacity of the gas-holder is such, that when raised to its highest point in the water, its height is equal to the radius of the base. It is usual, however, to increase this height by one or two feet, to prevent the possibility of the gas escaping from its under edge when raised to the greatest height in the water. For example, a gas-holder of the capacity of 30,000 cubic feet, has a diameter of 42 feet, and a height of 23. This was long considered to be the largest that could be conveniently made; but the Westminster Gas-works are provided with 18 large gasometers, of which the largest is 95 feet in diameter, 40 feet high, and of the capacity of 250,000 cubic feet; and at the present time telescope gasometers 160 feet in diameter are in use. The necessity for such abundant stowage will be apparent from the fact, that at these works a million and a half cubic feet of gas are produced every 24 hours during the winter months. These gas-holders are formed of sheet-iron plates, riveted together, and coated with tar on both sides, which makes the joints gas-tight. When the gas-holder is of large size, it is strengthened within with cross iron rods, and the top is supported by rods stretching obliquely down to the sides; the under edge is strengthened by curved cast-iron bars, bolted together, to which the oblique rods are attached. A number of rings at the top are connected to the upper ends of the supporting rods, and serve to suspend the gas-holder by a chain, which, passing over a pulley attached to a strong outer frame, has a counterpoise weight W, Fig. 1022, at the other end.

A common method of mounting gas-holders is shown in Fig. 1022. The gas-holder G dips into a tank of water T, rising above the surface of which are two pipes, one of which brings in the gas from the station meter, and the other conveys it to the main for distribution. With large gasometers this great body of water is an inconvenience, especially in frosty weather, when, to prevent freezing, steam must be introduced. Hence the arrangement shown in Figs. 1028, 1029, is to be preferred. In this a central core of masonry, brickwork, or sheet-iron, takes the place of the great body of water, and the only water required is that in the ring-shaped space surrounding the core. In the centre of this core are two channels for the two pipes *a* and *b*, by one of which the gas enters the gas-holder, and by the other it escapes into the street mains. The gas-holder, if small, is suspended from its centre by a chain, as in Fig. 1022, and to the pillars of the triangular or polygonal cast-iron frame guiding-rollers are attached, to keep the cylinder horizontal, and enable it to move easily.

By this method of suspension with the chain and counterpoise, the greater part of the weight of the gas-holder is taken off, and only so much left as is necessary to expel the gas. This weight must, however, vary in proportion to the sinking of the gasometer; it must lose a portion of its weight equal to that of the water displaced by the submerged portion; and hence the pressure of the gasometer on the contained gas would vary according to its depth were it not for an ingenious contrivance. The chain which bears the counterpoise is so adjusted as to equal one-half the weight which the gas-holder loses by immersion: the weight lost by the gas-holder in sinking is replaced by a portion of the chain coming over the pulley and balancing an equal portion of the chain on the other side, which is the same thing as adding one-half of

this portion to the side of the gasometer. By a nice adjustment of weight and bulk, very large gas-holders have been constructed without chains or weights, the buoyancy of the gas serving in all positions instead of a counterweight. The pressure to which the gas is subjected is generally such as will sustain a column of from 1 to 2 inches of water.[1]

The large amount of space required for the above description of gasometer, has led to the invention of what is called the *telescope gasometer*, which, with the same diameter, will accommodate a larger volume of gas without increasing the area of the ground. This gasometer, shown full and empty in Figs. 1028, 1029, con-

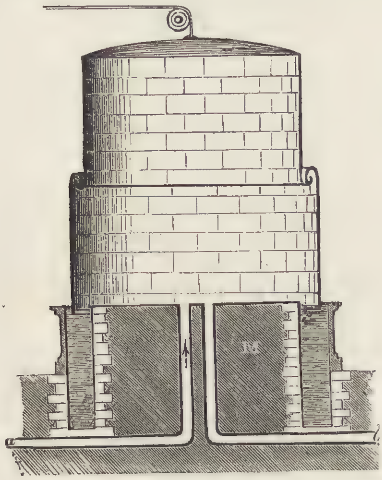


Fig. 1028. TELESCOPE GASOMETER, FULL.

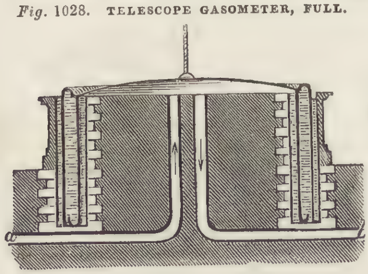


Fig. 1029. TELESCOPE GASOMETER, EMPTY.

sists of 2, 3, or more concentric cylinders, the bottoms and tops of which, except the uppermost, are furnished with flanges turned in opposite directions; the flange turning outwards and upwards at the bottom, and inwards and downwards at the top. The uppermost cylinder is covered at the top, but the others are open both at top and bottom. Now, supposing the cylinders to be all sunk in the cistern, and gas to be introduced, the innermost cylinder will rise first, and when its bottom reaches nearly to the surface of the water, its curved flange catches the flange of the next cylinder, which also rises; and when this has advanced sufficiently high it lifts the next. The escape of the gas, and the admission of air, are prevented by the lower flange of each cylinder taking up a quantity of water, which acts as a *water lute.* These gasometers are usually suspended at three points in their circumference, by means of three chains running over pulleys attached to three pairs of pillars. The larger ones, not telescopic, have commonly 8 or 12 such supports, and being decorated in the style of ancient amphitheatres, are often imposing in appearance.

The gas is distributed to the streets and houses of the town or district by means of cast-iron pipes, 9 or 10 feet long, cast with a turned up margin or shoulder at one end, and a mouth-piece at the other, as in Fig. 1031. When placed together, the space between them is filled up with greased tow and leaded all round, so as to be perfectly air-tight.[2] The smaller pipes for the supply of houses are often drawn leaden or pewter tubes,

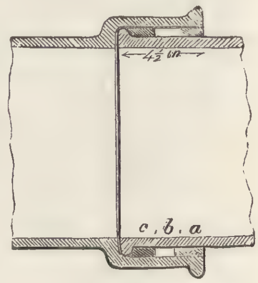


Fig. 1031.

but they ought to be of iron; for if a leak in the pewter pipes take fire, the surrounding metal will melt, and the hole enlarge until the flame becomes dangerous. The supply of gas to the mains is a matter of importance, not only as regards the convenience of the consumer, but the economy and consequent success of the works. In the dark evenings of winter the mains must be kept well filled with gas under a certain pressure; when the shops are closed this pressure must be moderated, so as to suit the diminished consumption, and yet be sufficient to keep the street lamps and the lights of private houses burning; towards sunrise this pressure must be diminished, and at a certain hour, varying with the season, cease altogether. Thus it will be seen that the pressure is a constantly varying quantity, which requires nice attention on the part of the superintendent.

One of the metropolitan districts supplied by a single gas company, is divided into a number of sub-

(1) The gage attached to various forms of apparatus in the gas-works for ascertaining the pressure of the gas, is a bent graduated glass tube, containing water or mercury, open at one end, and with the other end screwed into the vessel containing the gas. Thus, if the end *b* of the tube, Fig. 1030, be screwed into a vessel containing gas of the same pressure as the external air, the liquid will be of the same height in the two limbs of the gage. If the pressure of the gas be greater than that of the external air, the liquid will rise in the tube *a*, and the pressure of the gas will be 1, 2, or more inches, according to the height to which the liquid rises. If, on the contrary, the pressure of the gas be less than that of the outer air, the atmospheric pressure always acting at the open end *a* of the tube, will prevail, and the liquid will rise in the limb *b*.

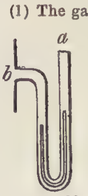


Fig. 1030.

(2) According to Mr. Clegg, lead joints are not to be depended on. His directions for making a joint are as follows:—"Caulk into the bottom of the socket, to the depth of about 2 inches, white rope yarn, well covered with putty; then, at the lip of the socket, caulk in tarred gaskets of such a thickness that it will just fit into the annular space left between the pipe and the socket, and to such a depth that a space of about 1½ inch will be left between the two yarns all round the pipe. At the top of the socket, where the ends of the tar-gaskets meet, draw up a portion to form a *gate*, exactly in the same way as for running a lead joint. Take 2 parts of melted Russian tallow, and 1 part of common vegetable oil, and pour the mixture, while warm, into the *gate;* it will run into and fill up the space between the two yarns. As the mixture does not contract in cooling, and is quite impervious to the air, it must form an air-tight joint. *a*, Fig. 1031, is the tarred rope-yarn, *b* the tallow and oil, and *c* the puttied white yarn.

districts, each of which consumes a variable quantity of gas, some more and some less. A division containing numerous shops will consume more than one consisting chiefly of private houses; so that the pressure for the one requires to be greater than that for the other. The Westminster district, for example, has about 20 such divisions, comprising nearly 150 miles of main, and the varying pressures required by each division are managed in the following manner:—

In the superintendent's room is a number of small gasometers, called *pressure indicators*, and painted over each is the name of the sub-district intended to be supplied. Each gasometer, A, Fig. 1032, is about 12 inches in diameter; it is supported in a tank of water in such a manner that it can rise and fall according to the pressure in the mains, with which it is connected by means of the small pipe B. To the upper part of each gasometer is attached a vertical rod C, carrying a black-lead pencil, which is made to bear upon a cylinder D, covered with a sheet of paper along the top of which are marked the 24 hours of the day. From these hours perpendicular lines are drawn to the bottom of the sheet: the paper is also ruled horizontally, and marked from the bottom, showing tenths. By connecting the cylinder with a time-piece, it is made to rotate on its axis, by which means the pencil draws a line opposite the hour when it is set going. If the pressure be constant for a number of hours, this line will of course be a circle, or a portion thereof, round the cylinder, parallel with the top and bottom edges of the paper, or a straight line when the paper is unrolled; if the pressure vary, the line will be diagonal or zigzag. At the end of 24 hours the paper is taken off the cylinder and a new one added. All these papers are preserved in portfolios, each one for its own division, so that the Company has a permanent record of the care and attention of the superintendent, an accurate referee in case of complaints from customers of insufficient supply, and an index of the gaseous wants of the district, or of any one of its divisions, to which light is dispensed.

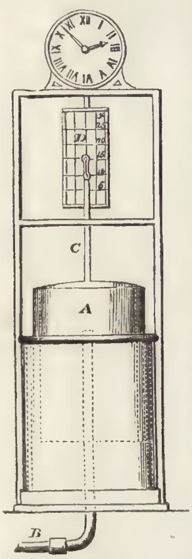


Fig. 1032.

In smaller works, where the district is supplied with gas without such a system of subdivision, the pressure is regulated by an apparatus called the *governor*. This is a self-acting instrument, and regulates the supply according to the demand. The governor consists of a cast-iron tank, *a a*, Fig. 1033, containing water, in which the regulating vessel *b b* floats; *c* is a cone of cast-iron, suspended by an eye-bolt to the top of the floating vessel; *d* is the pipe by which the gas enters; on the top of this pipe is a plate *i* furnished with an aperture which fits the diameter of the cone at the base, forming what is called a *throttle-valve*, so that if this were raised to its full height it would completely shut off the gas, and prevent it from entering the vessel; *e* is the outlet pipe, by which the gas escapes to the street mains. By adjusting the counterbalance *f* an increase or decrease of pressure may be produced. The outlet pipe *e* communicates with the mains, and the inlet pipe *d* with one of the gasometers of the works. Now it will be evident, that if the density of the gas in the inlet pipe becomes by any means increased, a larger quantity of gas must pass between the sides of the adjusting cone and the aperture in the plate *i*, the consequence of which will be, that the floating vessel *b b* will rise, and thereby contract the area of the opening in *i*; if, on the contrary, the gas in the inlet pipe decrease in density, the vessel will descend, and thus enlarge the opening *i*; so that whatever density the gas may at any time assume in the Company's gasometers or mains, its pressure in the floating vessel will be uniform, and, consequently, the velocity of the gas passing into the mains will be regular; for, when the aperture of the plate *i* would admit more gas than necessary for the supply to the mains, the floating vessel rises, and diminishes the orifice of the inlet pipe; and when, on the contrary, the inlet does not allow a sufficient quantity of gas to come from the gasometers, the gas passes out of the governor into the mains, and, in so doing, the vessel descends, and increases the orifice of the inlet pipe to admit more gas into the mains. A more compact arrangement of the above has lately been registered, under the title of "Glover's gas-light economic regulator."

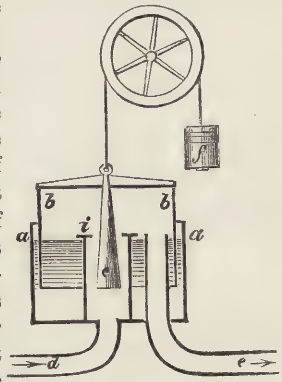


Fig. 1033. THE GOVERNOR.

The water gas-meter, by which the consumer registers his consumption, may be thus illustrated:—When a number of vessels of a known capacity, such as one cubic foot each, are arranged round a central axis in such a manner that, without any loss of gas, one after the other shall be filled with the gas in revolving, and for this purpose are inverted in water, it follows that just as many cubic feet of gas will have passed as there are vessels that have been filled. Suppose there are four such vessels: as each in succession fills and rises, the axis will be turned once round, thereby indicating the passage of four cubic feet of gas. In the gas-meter shown in section, Fig. 1034, instead of

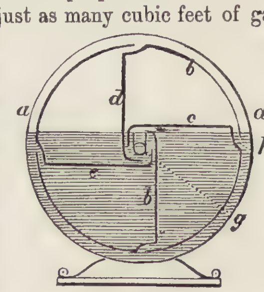


Fig. 1034.

four separate vessels, there is within an outer case *a a* more than half filled with water, a drum *b* moving round on two pivots, and divided into four compartments, *b*, *c*, *d*, *e*, by as many bent partitions, but enclosed at front and back by straight sides. The partitions are bent round, so as to form a central space *g*, and thus the gas can pass from one division into the next, and also escape into the outer case *a a* by slits in the rim of the drum. The gas enters at the back of the outer case by a pipe, which proceeds into the central space, where it turns up, and rises a little above the level of the water. One of the pivots on which the drum works is fixed in the bend of this tube. A peg on one of the straight sides at the back is the other pivot, and carries a toothed wheel. As one partition gets filled with gas, it becomes lighter, and rises, thereby causing the drum to perform a portion of a revolution. In Fig. 1034, the pipe *g* is pouring gas into the division in the direction of the arrow. As the gas accumulates in it, it gradually lifts this division out of the water, and brings the compartment *b e* into the same position. As this gets filled, and ascends, the compartment *d* comes round; then *c b*, which, being filled, and rising, completes one whole revolution. Now it will be seen, that as each compartment rises above the level of the water, the gas contained in it passes out through the slit into the outer case, and from that along a tube at the top of the case for supplying the burner. Thus, while one partition is rising, another is being brought under the water; and while the one is parting with its gas, the other is being filled, and so on. The toothed wheel gives motion to a train of wheels, adjusted so as to represent, by means of hands moving round dial plates, the units, tens, hundreds, and thousands of revolutions of the drum, by which means, the quantity of gas passed through the meter can be read off in cubic feet. All this may be further illustrated by Figs. 1035, 1036. In Fig. 1036, the direction of the gas is marked by arrows. The box *a*, in which the inlet valve is contained, is soldered tight, having no communication with the rest of the case, except through the valve, the position of which is shown by the arrows: *b* is the inlet pipe projecting above the water line, conveying the gas into the meter by the bent arm *c*, Fig. 1035, rising above the water between the convex cover and the inlet hoods. *d* is a float attached to the inlet valve, adjusted so that when the water falls below the centre opening, the valve will close, and the gas cease to enter the meter. Motion is communicated to the train of wheel-work behind the index from a spiral worm *w*, Fig. 1036, fixed on to the axis of the drum working into a wheel, the spindle of which passes through the tube *t*, sealed by dipping under the water contained in the case.

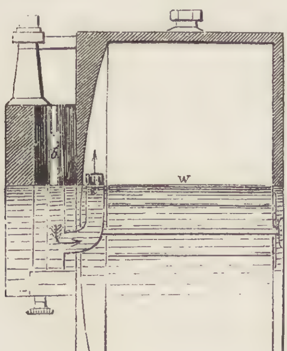


Fig. 1035.

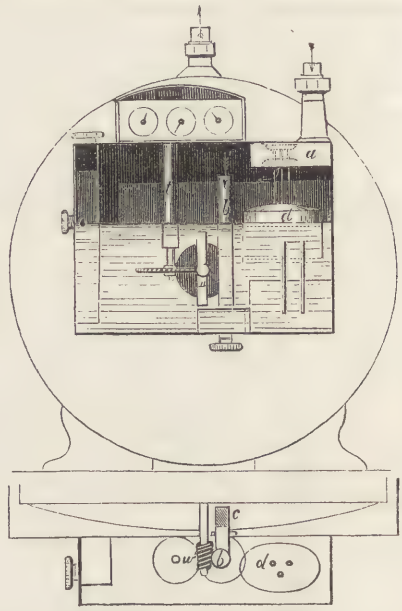


Fig. 1036. WATER GAS-METER.

This form of meter is not free from objections. The water is liable to freeze in cold weather, whereby the passage of the gas is completely stopped. Mr. Lowe has proposed the use of a solution of caustic potash or soda, which is not readily affected by frost, to replace the water in the meter: this would also tend to render the gas more pure, should either carbonic acid or sulphuretted hydrogen have escaped the purifiers at the works. Another objection is, that if the water-level be lowered, so that the same compartment may communicate at once with the central and outer spaces *g* and *a a*, Fig. 1034, more gas will pass than can be registered. Or if the meter be tilted forwards, the gas will pass without being registered at all. By this means, the Company is liable to fraud on the part of dishonest persons. Other meters have been invented which have not these objections, such as the *dry gas-meter*, in which the measuring chambers are separated from each other by flexible partitions of leather.

In the dry meter the gas is measured by the number of times that a certain bulk will fill a chamber capable of undergoing contraction and expansion by the passage of the gas. These alternate contractions and expansions of the chamber give motion to certain valves and arms of simple construction, which, by the aid of a few wheels, are made to turn the hand of a dial, as in the wet meter. In Defries's meter there are 3 measuring chambers, separated from each other by flexible partitions of leather, partially protected by metal plates. The pressure of the gas, expanding the flexible partitions, makes them assume the form of a cone on either side, the motion of which backwards

and forwards on both sides sets the measuring machinery in motion. By an action somewhat similar to that of a three-throw pump, a continuous stream of gas is forced out of the machine, it having been found that with only two flexible partitions the lights were liable to oscillation.

The constant bending of the leather backwards and forwards soon causes this meter to get out of order; and it may even happen that one partition may give way without its being discovered, so that a customer burning a large quantity of gas would have only a small quantity registered. Various devices have been attempted, and many patents taken out, to remedy the evil and to produce a dry meter free from objection. As far as we have been able to judge, the meter by Messrs. Croll and Glover is the most successful. In this meter, leather is indeed used, but merely to form a flexible band, which does not take any part in the measuring. The external form of the meter is that of an oblong box of iron plate or galvanised iron. Fig. 1037 is a front, Fig. 1038 a side-view, and Fig. 1039 shows the connexion between the measuring apparatus and the index, as seen in looking down upon the top of the meter. In the meter itself the interior is not visible, but in our figures we have supposed the sides to be of glass, instead of sheet-iron, for the purpose of showing the interior arrangements. The interior consists of two short cylinders closed at one end, and separated from each other by the plate P, Fig. 1038, and closed at the other ends by the discs A A. Now these cylinders may be compared to a steam-engine with two cylinders

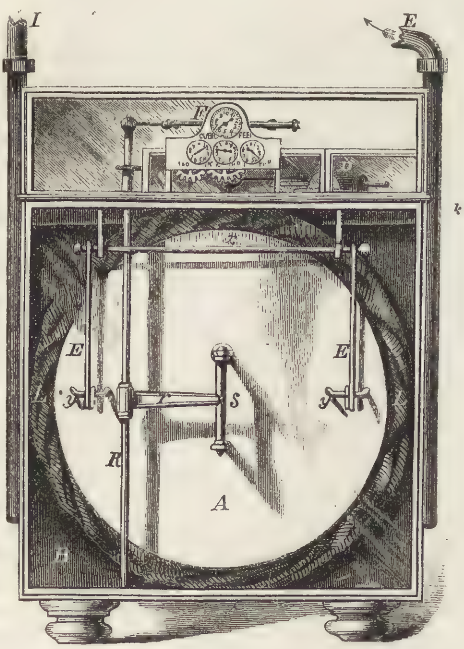


Fig. 1037. CROLL AND GLOVER'S DRY METER.

placed in opposite directions, in which, while the piston is descending in one it is ascending in the other, and *vice versâ;* with this difference, however, that instead of pistons working in cylinders, the disc end of each cylinder works backwards and forwards; for which purpose each disc is attached to the partition P by

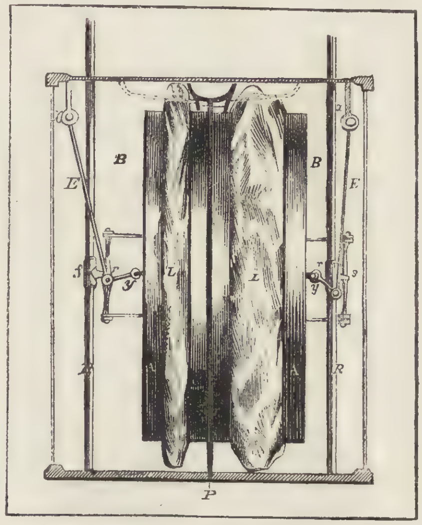


Fig. 1038. SIDE ELEVATION.

means of leather joints, L L, which act as hinges, and allow each disc, A, to move in towards P, and force out the gas contained in it, or to recede from P while it is swelling out under a fresh supply. Now the comparison with the steam-engine will be more evident if we consider that, while one drum is being filled the disc of that drum is expelling the gas on the other side to supply the burners, and the other cylinder and disc are alternately performing the same functions. The discs A A, therefore, act the part of pistons, and by their motion to and fro afford the means of measurement: they are kept in place by a hinge joint, *s*, attached to the upright rods R R. E E are parallel motions attached to each disc and to the top plate of the meter. The band of leather, L, as already mentioned, does not assist in measuring the gas, so that its contraction or expansion only decreases, or increases the capacity of the hinge, the disc being still at liberty to move through the required space only. The leather is so attached that it can bend only in one direction, which renders it much more durable than in Defries's meter. Now, as the gas passes into the enclosed space, and by its equal pressure distends the drum, the disc A is kept parallel with the partition P by the arrangement of levers, E y, E y, and x. This parallel

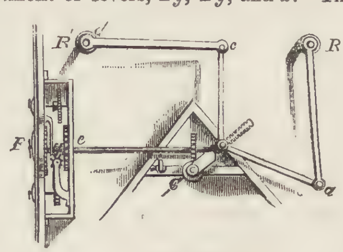


Fig. 1039.

motion also causes the rods R, one of which is situated on each side of the meter, to move each through the

half of a circle, by means of the jointed levers, *s r*, attached to them. At the top of these rods are two arms, R′ *d c* and R *a*, Fig. 1039, each of which, participating in the motion of the rods R R, describes alternately the arc of a circle. A rotatory motion is obtained by means of two connecting rods, *a b*, *c b*, Fig. 1039, attached to these arms, and also fitted to two other arms which work two D valves, D D, sliding backwards and forwards over three apertures, 1, 2, 3, Fig. 1040; of which apertures, Nos. 1 and 3 lead to the inside and outside of the cylinders respectively, and No. 2 to the exit pipe E, Fig. 1037. Now it is the duty of these valves to

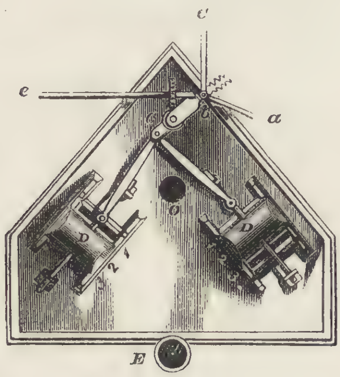


Fig. 1040.

regulate the flow of gas into and out of the two chambers of each division of the instrument; or, to return to the comparison of the steam-engine cylinders, to admit steam or gas to the cylinders above and below the pistons. In the case before us the gas is made to flow into the cylinder to distend it, and in doing so, expels the gas on the other side of its disc to the outlet E in connexion with the burners. This being done, the valve is immediately reversed, and gas enters on the side of the disc from whence it was last expelled. This process is alternately performed by the other disc. The equal and continuous flow of gas is obtained by the two valves, D D, being placed at right angles to the double-cranked shaft, and the two cranks on the shaft being at an angle of 45° to each other. By this arrangement, in proportion as the one valve closes, the other opens: but the closed valve always begins to open before the other is quite shut.

Let us now trace the course of the gas in its passage through the meter. But first it must be clearly understood, that the force which sets in motion the various parts of the meter is the gas itself, which is placed under pressure at the gas-works, as already explained, in order that it may be driven in a continuous stream along the mains, through the meters, and up to the burners of the consumers. That this pressure is amply sufficient for the purpose, will be evident, when it is considered that the pressure of only half-an-inch of water, multiplied into the area of the disc A, Fig. 1037, which, in a ten-light meter, is 10 inches in diameter, will amount to many pounds. Now, suppose a continuous stream of gas under pressure to be passing down the inlet pipe I, Fig. 1037. It proceeds as far as *i*,[1] at which point it meets with a horizontal tube which conducts it into the triangular chamber, Fig. 1040, by the hole O. Then passing down the open slit No. 1, Fig. 1040, it enters into one of the cylinders, distends it, and forces the gas which was on the outside of the disc to escape through No. 2 along a tube conducting to the exit pipe E, Fig. 1040, or E, Fig. 1037; this tube being on the level of *k*, Fig. 1037. Now, while this action is going on—while the cylinder on one side is being distended—that on the other is already full, the gas is shut off from it, and made to pass on the outside, where, exerting its pressure on the disc A, Fig. 1037, it forces it inwards, and the gas escapes along a short pipe attached to either side of the partition P into No. 2 of Fig. 1040, and so escapes to E. In Fig. 1041, the direction of the gas is marked by the arrows: it is passing from O, Fig. 1040, down the aperture 1, Figs. 1040 and 1041, which leads to the inside of the cylinder. From this it is pressed through No. 3 into No. 2, and so to the burner.

The triangular chamber, Fig. 1040, and D, Fig. 1037, has no connexion with the cylinders, &c. below it, except through the tubes already indicated; and the train of wheels, F, Fig. 1037, is also so boxed in as not to be exposed to the corroding action of the gas. The rods R R pass into this upper compartment through leathern washers and a stuffing of Berlin wool.

The circular motion of the double crank is transmitted by means of an endless screw and a spur-wheel, Figs. 1039 and 1041, along a wire *e*, Fig. 1039,

Fig. 1041.

to a simple train of wheels, which record their revolutions on the face of the dial F. This dial, Fig. 1042, consists of hands moving round circles which register the number of cubic feet of gas consumed, in units, tens, hundreds, thousands, &c. The top circle registers units: the

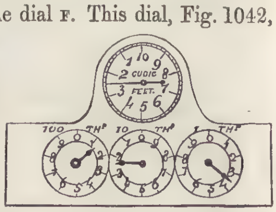


Fig. 1042.

right-hand circle hundreds; that is, the motion of the hand from 0 to 1 shows that 100 cubic feet of gas have passed through the meter; and, of course, a complete revolution of this hand indicates ten times that quantity, or 1,000 cubic feet. So the motion of the hand of the centre circle from 0 to 1 indicates 1,000 feet; and a complete revolution 10,000 feet. The motion of the hand from 0 to 1 of the left-hand circle indicates 10,000, and a complete revolution 100,000 cubic feet. Now, in reading off the numbers on the circles, we must take the number at which the hand is pointing, or the *lower* of the two numbers that the hand may happen to be between. If, for example, the

(1) The pipe is extended considerably lower, as seen in Fig. 1037, in order to catch any deposit of moisture or impurity and thus prevent it from entering the meter

hand be anywhere between 5 and 6, on any one of the circles, 5 is to be taken. Commencing, then, at the left hand, the hand is between 1 and 2: write down

10,000
2,000 for the middle circle,
300 for the right-hand circle.

12,300

Now, suppose that in taking the register three months before, the quantity had been set down as 9,100; then, subtracting this from 12,300 gives 3,200 cubic feet of gas as the consumption for three months.

The top or units dial is not used in registering: its use is to indicate to the collector, and also to the consumer that the meter is acting properly; for they could not, of course, wait while 100 feet were being registered.

The profitable consumption of gas, whereby the greatest quantity of light is obtained at the least expenditure of gas, depends, in great measure, upon the form of the burner, and the mode by which the flame is supplied with the air necessary for its combustion. Such arrangements must be made as will ensure the complete combustion of the gas; that is, there must be a sufficient supply of oxygen to convert the carbon of the gas into carbonic acid, and the hydrogen of the gas into water. If the supply of oxygen be deficient, the flame will be smoky from excess of carbon, and much light will be lost.[1] In such a case, the obvious remedy is, either to diminish the supply of gas, or increase the supply of air. This may be done by modifying the form of the gas-burner, or of its glass chimney. With respect to the form of the burner, it has been found by experiment that a plain jet $\frac{1}{4}$ inch in diameter at the orifice, will not give a flame free from smoke of a greater height than $2\frac{1}{2}$ inches; but the same quantity of gas which would give a smoky flame from a plain jet, will burn with a clear bright flame by extending or dividing the aperture of the jet, so as to expose a larger surface of flame to the air. It is not, however, necessary to increase the size or superficial area of the flame. It may even be diminished with increased luminous effect, by having two small apertures instead of one large one, by making them follow an oblique direction, so that the jets may cross each other. This forms the *fish-tail* flame. By having three apertures, we get what is called the *cock-spur*, Fig. 1043. The light may be still further improved by making a number of small apertures so near, that all the jets unite laterally into one, as in the *union* jet, Fig. 1044. Instead of these methods of improving on the single round jet, there may be a slit across the top of the beak, so as to give a sheet of flame, as in the *bat-wing* jet, the *swallow-tail*, and *fan* jets, Fig. 1045. In the Argand burner,


Fig. 1043.


Fig. 1044.

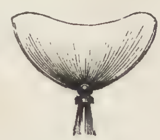


Fig. 1045.

a circle of small holes of equal size supplies the gas, and a current of air is admitted through the centre of the flame.[2] With such an arrangement, there is a larger amount of combustion, and consequently a higher temperature than in the plain jet; but with the same consumption of gas, the Argand burner does not give so much light as the flat flames of the fish-tail and bat-wing burners. An Argand burner, which consumes $1\frac{1}{2}$ cubic feet of gas per hour, affords light equal to that of 1 candle; an Argand consuming 2 cubic feet per hour, is equal to 4 candles; and when the consumption is 3 cubic feet per hour, it is equal to 10 candles. [See PHOTOMETER—LAMP.] In this experiment, however, the quality of the gas is not stated.

The construction of the chimney has an important influence on the proportion of air brought into contact with the surface of the flame. An unsteady smoky flame immediately becomes converted into a bright brilliant one, by putting over it the glass chimney; for by this means the quantity of air or draught is increased. But the form and dimensions of the chimney are important to be considered. A short, wide, cylindrical chimney scarcely increases or diminishes the proportion of air. Its advantage is to steady the flame; but if the chimney be moderately tall and narrow, or contracted towards the top, as in Fig. 1046, or suddenly contracted near the bottom, as in Fig. 1047, the draught becomes greatly increased, and the light improved. The supply of air to the flame may, however, be too abundant, so that instead of assisting combustion, it may, by cooling the flame, interfere therewith. Such is often the case with the cylindrical chimney, and it was remedied soon after Ami Argand's invention in 1789, [see ARGAND LAMP,] by contracting the diameter of the glass chimney at a certain height above the burner, so as to form a shoulder a few lines in width, as in Fig. 1048. The draught, as it enters the cylinder, has its direction changed at the shoulder, and is thus thrown upon the flame at a certain angle. By this contrivance the supply of air is diminished, but it acts in a more advan-


Fig. 1046.


Fig. 1047.


Fig. 1048

(1) It appears from the experiments of Dr. Henry, that those substances which give most light in burning, produce the most brilliantly illuminating gas when distilled; and that the illuminating power of a gas is proportionate to the quantity of oxygen required to consume it. Thus the illuminating powers of the following gases increase with the quantity of oxygen required for the combustion:—

100 measures of	hydrogen require	50	measures of oxygen.
,,	Dried peat gas ...	68	,,
,,	Oak-wood gas ...	54	,,
,,	Cannel coal gas	170	,,
,,	Lamp-oil gas ...	190	,,
,,	Wax gas	220	,,
,,	Pure olefiant gas	284	,,

(2) In the original Bude-light proposed by Gurney, oxygen gas instead of air was passed through the flame, whereby its brilliancy was greatly improved. The present Bude-light is a gas flame with two, three, or more concentric burners, with chimneys supplied with common air, and a reflecting apparatus of peculiar construction.

tageous direction, and instead of cooling the flame, assists the combustion, and increases the illuminating power. We are not sure but that the best form of chimney remains to be discovered.

In the use of gas-lights within doors, some provision ought to be made for ventilation. One part by weight of good coal-gas produces nearly three parts by weight, or about its own bulk, of carbonic acid gas, which, in moderate quantities, is fatal to animal life, and in crowded rooms and assemblies, where ventilation is not attended to, produces head-ache, fainting, palpitation, and other distressing symptoms. But in addition to carbonic acid, sulphurous acid is one of the results of the combustion of coal-gas, owing to the presence of certain sulphurous compounds which the purification of the gas does not wholly remove. This sulphurous acid, in contact with the air, becomes converted into sulphuric acid, the corrosive action of which is exerted on the walls and furniture, books, pictures, &c. The hydrogen of the gas produces water during the combustion, and this often serves as a vehicle for conveying some of the other products of combustion.

With the view of getting rid of these noxious vapours, there is sometimes suspended above the chimney a bell-shaped vessel, from the upper part of which proceeds a narrow tube, leading out of the apartment. By this means the vapours are carried away, more or less perfectly; but if the tube be of great length, the contents get cold and cease to be carried off; so that the ventilation stops, and the vapours get diffused over the room. The water produced by the hydrogen may even become condensed, and, flowing back along the tube, extinguish the flame. By a contrivance of Dr. Faraday, the bell-vessel is rejected, and a copper tube, of about the same diameter as that of the flame, conducted from its summit out of the apartment: this tube becoming heated, a rapid current is established, and the products of combustion effectually carried away. By another contrivance of the same distinguished philosopher, the ventilating current is made to descend between two concentric glass chimneys, of unequal height, the lower one being the interior, and the upper one covered with a disc of talc. When the current has reached the bottom, it passes away by a ventilating tube bending upwards. The descending current is established by applying heat to the bend of the ventilating tube, where it begins to ascend; and when this current is fully established the gas is lighted, and the exterior or higher of the two chimneys is covered with the plate of mica. The burner is supplied with air in the ordinary way, and the products of combustion are carried from the top of the inner chimney down through the space between that and the exterior chimney into a box, in which terminates the ventilating pipe for conveying the vapours outside. A globe of ground glass, open only at bottom, is placed over the lamp. It is stated that, notwithstanding the two glass chimneys, a greater amount of light is obtained by this arrangement, and certainly a larger flame, than with the ordinary Argand burner.

In the manufacture of gas there are certain secondary products which remain to be accounted for. A ton of coals, weighing on an average 2,240lbs., yields—

1 chaldron of coke	=	1,494lbs.
12 gallons of tar	=	135 ,,
10 gallons of ammoniacal liquor	=	100 ,,
9,500 cubic feet of gas[1]	=	291 ,,
Loss	=	220 ,,
		2,240 lbs.

The coal, in the process of distillation, increases in bulk about 28 per cent. On an average, about two bushels of coke are obtained from a cwt. of coals, or about 66 per cent. of the original weight of coal. About 25 per cent. of the coke is used as fuel for heating the retorts, and the remainder is sold.

The tar and ammoniacal liquor or gas water are collected in the tar cistern, in which the tar occupies the lowest position. The ammoniacal liquor is used in the manufacture of sal ammoniac and carbonate of ammonia. The tar is used in the manufacture of patent fuel and of kreosote, and as a paint for palings, &c.; and in some gas-works it is used with the coke fuel for heating the retorts. By distillation, 100lbs. of the tar yield about 26lbs. of an oily liquid, known as *coal oil;* the light product which first distils over is *coal naphtha.* Pitch remains behind; and this is used largely for paying wooden piles, &c., and the bottoms of ships. It is cheaper than the pitch of wood-tar, but not of so good a quality. Coal naphtha is used extensively for dissolving caoutchouc, and also for burning in the naphtha lamp. By impregnating coal-gas with its vapour, the illuminating power of the gas is greatly increased. It was originally proposed by Mr. Lowe to fill the ordinary wet gas-meter, Fig. 1036, at the house of the consumer, with purified naphtha, which was to be kept filled to the same height from a reservoir in connexion with it, and thus the gas was to be measured and saturated with naphtha at the same time. The mode by which this object is at present attained, is by passing the gas through an ornamental vase, containing a sponge saturated with naphtha. This vase may be situated anywhere between the meter and the burner.

It was calculated a few years ago that the annual consumption of gas in London and the environs amounted to not less than 3,000 millions of cubic feet, the light produced by the combustion of which would be equal to that of 160 millions of pounds of tallow candles. The consumption at the present time is doubtless much increased. A short time ago, the annual consumption of coal by the London gas-companies was 350,000 tons. Above 900 tons per day are consumed in foggy weather in winter. From 1827 to 1839, the quantity of gas consumed in the Metropolis doubled what it had been from 1822 to 1827; and from 1837 to 1848, it again doubled what it was in the preceding ten years.

According to a rough estimate, 350,000 tons of

(1) One cubic foot of coal-gas weighs 214½ grains.

coal would produce nine times that sum in cubic feet as the annual supply of gas to the metropolis, of which the leakage and loss may be estimated at 20 per cent. The street-lamps are reckoned to burn 4,000 hours per annum, and generally consume 5 feet per hour. A glance at the gas-share list in the *Journal of Gas-lighting*, published every month, will show the enormous extension of this art throughout Great Britain and Ireland; and it will also be seen that many of the continental cities are lighted by English companies.

[The Editor has received from a distinguished scientific friend, the following account of the application of the refuse products of the Edinburgh Gas Works.]

The Edinburgh Gas-works are situated in the valley of the Canongate, which runs from west to east towards the sea, parallel to the High-street, and the North British Railway. The chemical works, where the products of the gas-works are turned to account, are distant about two miles from the latter, and the gas-works are at a lower level. The Calton Hill is interposed between the two manufactories; and at a former period the gas liquor was carted in barrels to Bonnington on the Water of Leith, where the chemical works are situated. Recently, however, the gas liquor has been lifted over the shoulder of the Calton Hill by an ingenious force-pump, and the difference of level is then sufficient to carry the liquor to Bonnington, which though higher than the Canongate is lower than the Calton Hill.

The liquor separates into two strata; the lower and heavier being TAR; the upper and lighter, an impure aqueous solution of carbonate and hydrosulphuret of ammonia; this is called the *ammoniacal liquor*. It is the less valuable of the two liquids, and is treated as follows:—To separate it from a portion of tar which always accompanies it, it is subjected to distillation. The distilled liquid is in greater part converted into sal ammoniac, but a considerable quantity is also manufactured into sulphate of ammonia.

The first step in the sal ammoniac process is, the neutralization of the distilled liquor with hydrochloric acid, which as well as sulphuric acid is made at the works. The neutralised solution is then pumped into large caldrons, where it is concentrated till it has reached the crystallising point. It is then drawn off into large vats or troughs, where as it cools it deposits multitudes of small feathery crystals, consisting of rows of minute octohedrons or allied forms attached to each other. In cold weather beautiful large cubes of sal ammoniac are sometimes produced.

The feathery crystals are transferred from the troughs to a drying apparatus, consisting of a shallow oblong open box, made of stone, and heated by a furnace below. The dried salt, in a state of granulation resembling brown sugar or salt, is then mixed with charcoal-powder, which is intended to reduce any oxide of iron present, so as to prevent a brown colour being given to the sal ammoniac when raised in vapour. The salt after this treatment is subjected to sublimation. The subliming vessels are shaped exactly like a man's hat, arranged in the furnace with the crown downwards. They are some three feet in depth, and two and a half in diameter. When charged with salt they contain a quantity of material sufficient to demand a week's unceasing application of heat for its sublimation. Each pot is covered by a leaden dome or cupola, which is luted on with clay, and has an aperture in the centre through which the salt is allowed to sublime away, for some period after the commencement of the process. This occasions a considerable loss of material, but no other way is known of securing a hard, coherent sublimate. There seems reason to believe that the presence of moisture in the imperfectly dried salt, is the cause of its condensing at the commencement of the process as a spongy mass. At all events a firm cake does not form till after some time. The workmen proceed empirically, and when they judge that a sufficient interval has elapsed, they close the central aperture in the leaden dome by a plug of clay, and the sublimation continues for a week. The hemispherical cakes of sal ammoniac thus produced, are rasped on their outer surfaces to remove any crust or colouring matter, and broken into wedges, which are packed in barrels and sent all over the world.[1]

Sulphate of ammonia is largely purchased by farmers in spring, and is used by the alum makers for their ammonia alum.

In preparing it, the distilled ammoniacal liquor is saturated with sulphuric acid, and then "*salted down*," *i. e.* concentrated till the hot solution precipitates small crystals. These are removed by colanders or perforated ladles, dried, and packed in barrels lined with paper. The sulphate of ammonia thus prepared, is believed to contain only one atom (*i. e.* the minimum quantity) of water of crystallisation.

The tar containing much water is transferred to a still heated by a naked fire, and sometimes, also, to a still through which steam is blown. In either case crude naphtha and the vapour of water distil over together, and are separated by their different densities. The naphtha is then digested with oil of vitriol in a leaden trough. Ammonia and various other substances are removed by this treatment, the *rationale* of which is but imperfectly understood. Quicklime is then added to remove the acid, after the naphtha has been washed with water, and the naphtha is distilled again. It is then ready for the market.

The tar from which the naphtha has been separated is transferred to another still, and heated by a naked flame to a much higher temperature than that applied to the crude tar accompanied by water in the first distillation. A less volatile liquid than naphtha is now yielded, which is termed pitch-oil, and has been largely used to impregnate wood so as to preserve it from the attacks of insects and from decay.

What is left in the still is run out hot. It hardens

(1) The Edinburgh sal ammoniac is sent to New York on the one hand, and to Petersburgh on the other. In Russia, sal ammoniac is used by the common people occasionally as a condiment, in preference to culinary salt. If the saliva be at all alkaline, as it often is, it liberates ammonia from the sal ammoniac, and occasions a peculiar and not very pleasant impression on the organs of taste.

into a soft solid, which in cold weather exhibits, when broken, the most perfect specimens imaginable of conchoidal fracture on the largest scale. No market at present exists for this pitch. It is used at the works to a small extent as fuel; and in districts where coal or wood are dear it would be of great value, could it be cheaply transported. If distilled at a red heat or thereabouts, it yields a third volatile liquid and coke.

At present no market, or almost none, can be found for the tar, which was formerly largely consumed at the sea-ports, and was sent up the Baltic and elsewhere. The multiplication of gas-works, however, on the continent, and the absence of duty on foreign as distinguished from British tar, has greatly lessened the sale of the latter abroad.

At Bonnington they also make sulphurous acid from oil of vitriol and vegetable matter (shellings). The acid is employed to saturate carbonate of soda; the resulting sulphite being sold to the paper-makers, who employ it, under the name of *antichlore*, to remove the last traces of chloride of lime from the rags which have been subjected to the bleaching process.

Oil and Resin Gas. In places where coal is difficult to procure, oil may be used in the manufacture of gas: the crudest oil, even pilchard dregs and the sediment of whale oil, are applicable to the purpose, and the process of manufacture is much more simple than in the case of coal; all that is necessary being to raise a small quantity of oil at a time to a high temperature. The apparatus invented by Messrs. Taylor, in 1815, consisted of a furnace, with a contorted iron tube, containing fragments of brick or coke, into which, when red-hot, the oil was allowed to drop. Decomposition of the oil immediately took place, gases were given off, together with the vapours of substances liquid at common temperatures, and there was a considerable deposit of carbon in the retort tube. By an improvement in this apparatus, the exit tube from the retort is conducted into an air-tight cistern or receiver, in which the more easily condensed products are collected in the liquid state, and returned into the retort. The gas proceeds from a pipe leading from the top of the cistern. In Fig. 1049, *a* is the retort, filled with pieces of coke about the size of a hen's egg; *b* the exit tube leading into the cistern *c*, from which the pipe *d* conducts the gas to the gasometer. The coke is changed every two or three weeks, as the interstices become obstructed by the deposit of carbon.

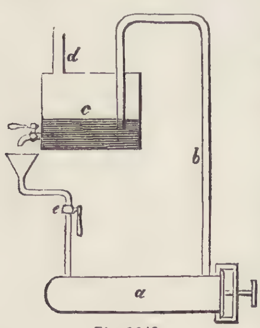


Fig. 1049.

Oil-gas is rich in olefiant gas: it contains neither nitrogen nor sulphuretted hydrogen; but it has more carbonic oxide than coal-gas. Its illuminating power is twice that of the best coal-gas, and three times that of ordinary coal-gas. The commonest oil is, however, too expensive in this country to admit of its substitution for coal. A great objection to oil-gas is the gradual liquefaction of some of its valuable hydrocarbons, by exposure to a moderate degree of cold.

Resin is admirably adapted to the manufacture of gas, but, as in the case of oil, its expense will always prevent its introduction where coal can be procured. The apparatus constructed by Professor Daniell for the Resin Gas Company at Bow, consisted of a retort *a*, Fig. 1050, charged with fragments of coke, heated to bright redness by a furnace underneath; a short exit tube *b* was placed below the retort, instead of a long one above it, as in Fig. 1049, the latter having become clogged by the bituminous matter which distilled from the resin; the exit tube *b* was passed into an air-tight cistern or hydraulic main *c*, kept cool by a refrigerator, supplied with water from a cistern above. The volatile oil condensing in *c*, was conducted into another cistern *d*, by the discharge pipe *e*. The uncondensed gases and vapours passed up the pipe *f*, and deposited a further portion of volatile oil in the cistern *g*, from which it was conducted into *d* by a syphon tube. From the cistern *g* the gas passed by the pipe *h* into the gasometer. The large quantity of volatile oil collected in this process, was employed to dissolve the resin in the vessel *i*, which was mixed with oil in the proportion of 8 or 10 lbs. of resin to 1 gallon of oil, the solution of the resin being assisted by the heat of the furnace below. The vessel *i* contained a wire-gauze screen, to prevent any solid resin or impurity from entering the retort; the dissolved resin passed through the stop-cock *k*, funnel, and syphon tube, into the retort. A little acetic acid formed in the oil during the distillation, was got rid of by the addition of lime, before the oil was mixed with the resin. It is stated that 1 cwt of resin will afford from 1,000 to 1,200 cubic feet of gas, of the average specific gravity 850, and that 2 cubic feet of resin-gas will afford as much light as 5 of coal-gas.

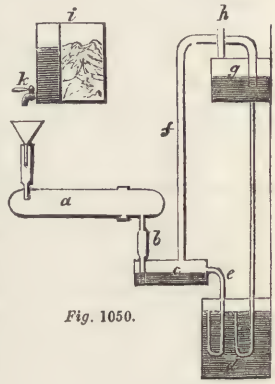


Fig. 1050.

The production of gas from oil, resin, and other refuse matter, has long been neglected in this country, on account of the expense of the crude material. Improved methods have, however, been introduced, and made the subject of a patent by Messrs. Laming and Evans, (dated 23d April, 1850.) According to their method, iron or clay[1] retorts are used; these

(1) One part of this patent is for the formation of clay retorts, by which it is proposed to mix with the fire-clay about 0·25 per cent. of its weight of asbestos, or fibrous silicate of magnesia. This is said to give greater tenacity to the retorts, making them less liable to crack when exposed to various ranges of temperature.

are composed of two horizontal chambers, one above the other, and communicating at the back only. The ends of the chamber are closed by three man-hole doors, two of which are secured over the front ends of the chambers, and the third, which is a large door, serves to close the hind ends of both chambers, the three doors all projecting beyond the brickwork setting of the retort. Near the front end of the upper chamber is an inverted funnel, of large diameter, closed by a lever, the edge of which is turned down, and dips into an hydraulic joint, or into a joint filled with metal fusible at the temperature to which it is exposed. The cover is fitted with a double syphon, furnished with a stop-cock. The eduction-pipe leading to the hydraulic main is connected with the front end of the lower chamber of the retort. When this apparatus has been raised to the usual temperature, the upper chamber is charged with coke, heaped up just beneath the funnel, and some pieces allowed to fall over against the large man-hole door at the back; the lower chamber is charged with coal or coke. A stream of oil, tar, melted pitch, resin, fat, or other analogous matter, in conjunction with water or not, is then allowed to fall from the double syphon, through the large funnel, upon the red-hot coke; it passes thence, partly as gas, and partly as liquid, through the upper chamber to the back of the lower one, along which it next proceeds, chiefly in the state of gas, and escapes, mixed with the gaseous products of the lower chamber, through the eduction-pipe into the hydraulic main. When the lower chamber is filled with coal, it is allowed to give off its gas, before the liquid is permitted to flow: the process is then continued without intermission, until the passages of the gas apparatus require to be opened and cleaned out.

WATER-GAS. The capital discovery of the composition of water, and the ease with which its two volumes of hydrogen can be separated from its one volume of oxygen, have caused scientific men to look forward—somewhat indefinitely, it is true—to the time when water may come to be used as a source both of light and of heat. The "manufacture of water-gas" is at the present time being keenly discussed,[1] and it has already formed the subject of several patents: viz. Donovan's patent, dated 1830; Lowe's, 1832; Manby's, 1839; Val Marino's, 1839; Radley's, 1845; Lowe's, 1846; White's, 1847. Of all these, probably, the most original and suggestive is Val Marino's; but our limits will not allow us to describe his processes and the causes of failure. The principle of the manufacture of water-gas is, to pass steam over red-hot coke, thereby resolving it into two inflammable gases, viz. hydrogen and carbonic oxide, and then to supply them with the requisite amount of carbon for luminosity, by passing them through a retort in which resin or some other carbonaceous substance is undergoing decomposition by heat. In a recent patent, Messrs. Barlow and Gore seem to have profited both by the failures and the successes of their predecessors. Their processes are based, *first*, upon an improved method of rendering luminous the gas resulting from the perfect decomposition of water or steam; and *secondly*, upon the *conservative influence* which hydrogen exercises in protecting the matter upon which the illuminating power of gas depends from decomposition by heat. The failure of previous patentees in the attainment of the first point is said to have arisen from the imperfect decomposition of the water or steam, and the production of a large quantity of vapour, which exerted a destructive influence on the carbonaceous matter undergoing decomposition for the purpose of rendering the water-gases luminous. Moreover, a considerable quantity of carbonic acid was produced, and this had to be got rid of by purifying, before the gas could be burnt. The present patentees propose to obviate these difficulties by first *condensing* the water-gases, so as to deprive them of excess of vapour, and then to pass them through a heated retort containing carbonaceous matter, by which the whole of the carbonic acid gas will be converted into twice its bulk of carbonic oxide gas, and the pure hydrogen and carbonic oxide gases, in equal volumes, free from carbonic acid, are afterwards admitted in regulated quantities into retorts where carbonaceous matter is undergoing distillation or decomposition, and by which they are rendered highly luminous. The conservative influence of hydrogen may be illustrated by the following experiment:—If olefiant gas be passed through a red-hot tube, the carbon will be deposited, and the gas be converted into light carburetted hydrogen; but if hydrogen be added to the olefiant gas, the same process may be repeated without causing any deposit of carbon, and with only a diminution of illuminating power in the mixed gases due to the increased volume of the hydrogen. The practical effect of this property when applied to gas-making is, to reduce the quantity of condensible products, such as tar, &c., and to prevent the deposit of carbon on the interior surfaces of the gas-retorts. According to the patentees, upwards of 50 per cent. may be added to the volume of gas yielded by all descriptions of materials ordinarily used for that purpose, without any diminution of the illuminating power; so that 15,000 cubic feet is said to be likely to be the future produce from one ton of Newcastle coal, and 75,000 cubic feet of London gas from the same quantity of Boghead cannel, the ashes of which may be used in the manufacture of alum, the residue after the extraction of the alumina being also valuable in the manufacture of pottery, porcelain, and glass, and also useful as a polishing-powder and decolorant.

GAUGING. See GAGING.

GAUZE. A light, transparent silk texture, supposed to have been invented at *Gaza*, in Palestine; whence the name.

GEARING, or GEERING. A term applied to those mechanical contrivances which are interposed between the prime mover and the working parts of machinery for the purpose of transmitting motion. The term is sometimes restricted to the series of toothed wheels by which motion is conducted from

(1) The reader interested in this subject will do well to consult the *Journal of Gas-lighting* for the end of 1851 and the beginning of 1852.

one revolving axis to another, without reference to the shafts and bearings by which they are supported. Two toothed wheels are said to be *in gear* when the teeth are engaged together; and *out of gear* when disengaged or separate. See COUPLINGS—WHEEL.

GELATINE is a substance the production of which is limited to the animal creation. When the skin and membranous tissues of animals are boiled in water, the liquor, on cooling, forms a jelly. The bones, tendons, and ligaments, under a higher temperature, also yield a jelly, similar in appearance and in properties to the former, but less agreeable to the taste. [See BONE.]

The ordinary sources of gelatine are clippings of hides, hoofs, horns, feet of calves, cows, sheep, pigs, and various membranes. These are carefully cleaned, then subjected to long boiling, and the liquor strained, skimmed, and allowed to gelatinize: the resulting jelly is stiff and tremulous, and is called *size*. Sometimes the sources from which size is obtained are not so pure as the above, the refuse from the skins of horses, cats, dogs, the cuttings from parchment, vellum, and white leather, and sometimes the membranous parts of fish, being admitted into its composition. Size has an intolerably putrid odour, but it may be purified by the careful application of sulphurous acid. This is sometimes done, the size dried in thin layers, and so used as a substitute for isinglass. Without purification, size is cut into slices, dried, and sold as *glue*.

Isinglass is the purest form of commercial gelatine. The best is prepared from the air-bladders and sounds of three or four species of sturgeon, inhabiting the Black and Caspian Seas, and their tributary streams. These tissues are cleansed, dried, and scraped, forming *leaf isinglass;* or they are twisted into various forms, and called *long* and *short staple;* or folded into packages, called *book-isinglass*. The manufacture is chiefly carried on in Russia, whence we receive the best article. The account given by Martius of the preparation of Russian isinglass is as follows: The swimming bladders of the fish are first placed in hot water, carefully deprived of adhering blood, cut open longitudinally, and exposed to the air, with the inner delicate silvery membrane upwards. When dried, this fine membrane is removed by beating and rubbing, and the swimming bladder is then made into different forms. An inferior variety, called *ribbon isinglass*, is received from America. Isinglass is cut by machinery into the delicate filaments in which we usually see it sold. It is a colourless, inodorous substance, perfectly soluble in hot water. It is largely consumed as an article of food. The purest and whitest isinglass is required for domestic use, entirely free from unpleasant odour, and dissolving readily and completely in water. It forms a very transparent jelly, and is indispensable in the preparation of blanc-mange, ices, creams, and other delicacies for dessert. Inferior isinglass answers the purpose of fining beer, &c. A solid gelatine in thin plates and strings, has lately been introduced to answer the purpose of isinglass. The best is transparent, and is brought from France; it is prepared from the gelatine of bones by digestion in dilute hydrochloric acid and long boiling in water. It is much cheaper than isinglass, but it is inferior in nutritive power and digestibility, properties which are diminished by long decoction. The same may be said of another substance called *patent opaque gelatine*, which is prepared from the cuttings of skins, and is therefore a kind of glue. Sources from which these substitutes are procured are not the most agreeable; nor is it likely that in the more delicate preparations of the table they will ever take the place of isinglass. Jellies were formerly supposed to be exceedingly nutritive, and especially suitable for invalids; at present medical testimony leads to the opinion that they are less so, and even less digestible than the flesh or muscular part of animals. Isinglass is made in India, and has long been exported thence to China. In most cases it has a very unpleasant fishy odour, which renders it totally unfit for domestic use. Cod sounds, in the dried state, are brought from Scotland, and used as a substitute for foreign isinglass.

Diamond cement, or white fish-glue, is made of isinglass dissolved in dilute spirits of wine or common gin. The two are mixed in a bottle loosely corked, and gently simmered in a vessel containing boiling water; in about an hour the isinglass will be dissolved, and ready for use. When cold, it should be an opaque, milk-white, hard jelly: it is remelted by immersion in warm water, but the cork should be at the same time loosened. After a time a little spirit should be added to replace that lost by evaporation.

But the best *isinglass glue* is made by first soaking good isinglass in cold water; when swelled, it is to be put into the spirit, and the bottle containing it set in a pipkin of cold water, which may be brought to the boiling point, when the isinglass will melt into a uniform jelly, free from lumps or strings. The addition of a little essential oil diminishes its tendency to become mouldy.

GLUE is a highly useful and important substance, and its manufacture is carried on upon a large scale, as follows: the parings of hides and pelts from the tanners' and furriers', with the refuse materials already enumerated for gelatine, are the substances from which it is extracted in Britain. These are first placed in a lime-pit, and when sufficiently steeped, they are carried in baskets to a stream of water and rinsed, after which they are placed on hurdles to dry. Whatever lime remains adhering to them is converted into chalk by the action of the air; and though lime would be injurious to the after processes, yet the presence of a small portion of chalk is immaterial.

The pieces having been thus cleansed, the next process is the extraction of the gelatine from them by boiling. For this purpose they are placed in a wide-mouthed bag or net, made of rope, and spread open within a large iron caldron. A light framing of iron within the caldron prevents the bag from sticking to its sides. Water is then added, and gradually brought to the boiling point; as the animal sub-

stances sink, fresh quantities are added, the whole being occasionally stirred up and pressed down with poles. The state of the substances is tested by occasionally taking out a portion, and setting it aside to cool: if a clear mass of jelly be produced, the boiling has been sufficient. The mouth of the bag is then closed by means of cords, and the bag is slowly hoisted by machinery until it rests against, or partly coils round a beam immediately over the caldron, which helps to press out the liquid. See Fig. 1051. In this state it is left to drain. Meanwhile the contents of

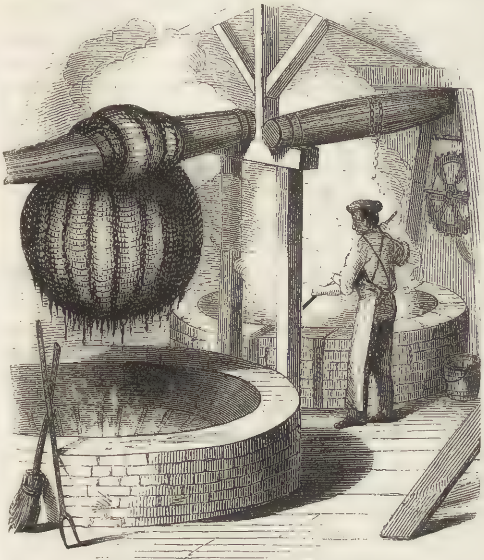


Fig. 1051. GLUE-CALDRONS.

the caldron, if not strong enough for glue, can be further evaporated by continuing to apply heat. The contents of the bag are boiled a second and a third time for making size; and when the solutions are too weak for either glue or size, they are economically used instead of water. The last remaining refuse is sold for manure. Thus, every portion of animal substance is turned to profitable use.

The glue in the caldron, when thick enough, is drawn off into a vessel called a *settling-back*, and maintained at a temperature which will keep it liquid. This gives time for the deposition of solid impurities, and for further clarification by the addition of such fining substances as the manufacturer may prefer. The glue is then run off into wooden coolers about six feet long, one foot broad, and two feet deep. Here it becomes a firm jelly, which is cut out by a spade into square cakes, each cake being deposited in a sort of wooden box, open in several slits or divisions to the back. The glue is cut into slices by passing a brass wire, attached to a kind of bow, along the slits. These slices are placed upon nets, (the marks of which are seen on the dry glue,) and stretched in wooden frames, and are thus removed to the glue-maker's field, where they are placed in piles, with proper intervals for the admission of air, each pile being roofed in, as a protection from the weather. The glue is turned two or three times a-day, and for this purpose the roof is lifted off the pile, and the uppermost frame placed on the ground. The cakes are turned one by one, and then the second frame is lifted off and placed on the first. The operation is thus repeated until a new pile is formed near the spot where the old one stood, when the roof is replaced.

During the drying the glue is more likely to receive injury than at any other period. In very warm weather the cakes are liable to become so soft as to lose all shape and unite with the frames, or they may even melt entirely, and flow away. A thunder-storm sometimes prevents a whole field of glue from hardening; while a thick fog may make it all mouldy. A brisk drying wind may harden it so suddenly as to render it unsightly and unfit for the market. A hard frost, by freezing the water in the glue, may cause it to crack in all directions, rendering re-melting necessary. Thus the manufacture has many vicissitudes to suffer, and can only be profitably and conveniently carried on in temperate and equable weather. The drying, however, is not entirely finished in the open air. When the glue is about three-parts dry, it is removed into lofts, where, in the course of some weeks or months, the hardening is completed. But as the surfaces of the cakes become mouldy and soiled, it is at length necessary to scour them with a scrubbing-brush and hot water, and set them up to drain. They are then finally dried off in a stove-room at an elevated temperature, which, when they are once solid, only serves to harden and improve them.

After stove-drying the glue is fit for the market, where it is judged of by its strong dark colour, and freedom from cloudy or black spots when held to the light. The better sorts of glue are transparent, especially the thin cakes of the *Salisbury glue*, which are of a clear amber colour. The best glue swells without melting when immersed in cold water, and renews its former size on drying. The method of softening it for use is to break it into small pieces, soak 24 hours in cold water, and then melt slowly over a fire with frequent stirring. When prepared in this way it cools down into a stiff jelly, which requires only a little warming to fit it for use. Glue must not be used in a freezing temperature.

A strong compound glue is made by infusing common glue in small pieces with isinglass in spirits of wine, just sufficient to cover the mixture. Heat is then cautiously applied, and when melted, powdered chalk is added, making the whole of an opaque white. A strong glue, which will resist water, is also obtained by adding half a pound of common isinglass to two quarts of skimmed milk, and evaporating the mixture to a proper consistence. If gelatine which has been swelled in cold water be immersed in linseed-oil and heated, it dissolves and forms a glue of remarkable tenacity, which, when once dry, perfectly resists damp. Ordinary glue may be thus dissolved, and a small quantity of red-lead, in powder, added.

It appears from the observations of M. Schattenmann, a glue-maker, (Annales de Chimie, 1845,) that fresh glue dries much more readily than glue that has been once or twice melted; and that dry glue steeped

in cold water absorbs different quantities of water according to the quality of the glue; and the proportion of water so absorbed may be used as a test of the quality of the glue.

It appears that fresh glue contains water of composition, or water more intimately united with the glue than water mixed with it in the process of melting, which admits of being readily disengaged by evaporation. The combined water of dry glue disappears in the course of successive meltings and solidifications to which glue is subjected. Glue in thin plates is usually of better quality than thick ones, even when made with the same kind of gelatine, because the thin plates admit of a more complete drying than the thick.

In applying M. Schattenmann's test, dry glue is immersed for 24 hours in water at the temperature of about 60° Fahr. A jelly will thus be formed, the qualities of which will fairly represent those of the glue. For example: the finest ordinary glue, or that made from white bones, absorbs 12 times its weight of water in 24 hours, so that a plate weighing 3 grammes produces 39 of fine elastic jelly. Glue from dark bones absorbs 9 times its weight of water, and produces not quite so fine a jelly. The ordinary glue of Alsace or of Germany, made from animal refuse, absorbs 5 times its weight of water, producing a soft brown jelly, without elasticity and consistence, and falling to pieces when handled. The common glue of Bologne absorbs 3½ times its weight of water.

Well dried glue is much less hygrometric than badly made glues, or those made of inferior materials. The latter are liable to putrefaction. The water of composition seems to be injurious to the strength of glue, which increases in proportion to its dryness.

Marine glue has no gelatine in its composition. It will be noticed in its proper place.

Glue or gelatine has lately been applied, with great success, to the formation of moulds for casting. The difficulties attending the use of sand, clay, plaster of Paris, wax, &c. in forming moulds for casting, are very great where the objects to be repeated are complicated in form. About the beginning of the present century the Germans introduced the use of glue for making moulds, which was not employed in this country until about the year 1826, when Mr. Douglas Fox used it to take casts from anatomical preparations, calcareous concretions, vegetable substances, &c.; and in order to give greater elasticity to the moulds so obtained, and to keep them in a fit state for use during a long period, he mixed treacle with the glue: this, however, was found to discolour the surface of all white bodies, and its application being limited by this objection, the plan was abandoned. About the year 1844 attention was again called to this subject by the production in France of a series of casts in imitation of ivory; and about 1846 the Society of Arts, London, offered a prize which was awarded to Mr. Franchi for his specimens of casting in plaster composition in imitation of ivory. At the time the award was made, the nature of the material used by him was not known; but it has since proved to be pure gelatine, and owing to the skilful use of his material some exquisite electro-type casts deposited in the Geological Museum were obtained from objects greatly under-cut. Mr. Franchi has since found that he can obtain from a gelatine mould a cast in gelatine in relief without losing any of the sharpness of the original. This has enabled him to apply objects modelled on flat surfaces to cylindrical bodies, thus saving the labour and expense of modelling. One great advantage of gelatine moulds is, that casts without seams can be taken from them.[1]

Gelatine in a great variety of forms and colours was displayed in the Great Exhibition, as has been noticed in our Introductory Essay.

GEMS. The various gems and precious stones used in the arts are noticed separately under their respective names. The conversion of gems to purposes of ornament will be described under LAPIDARY-WORK: for the art of engraving on gems we must refer to SEAL-ENGRAVING.

GERMAN SILVER. See NICKEL—PLATING.

GILDING. Gilding on wood is a distinct trade from gilding on metal; the processes and tools employed are likewise different. Gilding on wood is of two kinds, distinguished as *burnish-gilding* and *oil-gilding*. The processes connected with burnish-gilding are as follows. If a plain picture-frame has to be gilded, the gilder receives it from the hands of the joiner, not in the shape of a picture-frame, but in one long levelled moulding extending 12 feet in a straight line. This he has to prime and prepare for gilding by a number of processes, which cannot be abridged without detriment to the final effect. He first gives it a priming of hot size and whiting, called *thin-white*. The size and also the whiting employed for this purpose must be of the best kind, the whiting being finely powdered and stirred in, in small quantity, while the size is being melted in an earthen pipkin. This first coating of thin-white being dry, all holes and irregularities in the moulding are afterwards filled up with a mixture of whiting and size made of the consistence of putty, but differing from ordinary putty in containing no oil. After this, the moulding receives four or five layers similar to the first, but of greater consistence, and therefore called *thick-white*. These are laid on with a brush, and time is allowed between each layer for the work to dry. That the fine work of the moulding may not be filled up, opening tools, such as crooks, chisels, gouges, &c. are employed while the thick-white is still wet. The forms of the various mouldings are perhaps better retained by using the *double-opening-white*, that is, two thick whites laid on, the one almost immediately after the other, and worked into the shape of the mouldings, by hard stones of the required form, used in conjunction with the opening tools.

The body of the whiting, which is now from one-sixteenth to one-twelfth of an inch in thickness, is necessarily uneven at the edges, so as to require trimming. This is the next operation, after which the whole is smoothed by pieces of pumice-stone,

(1) Journal of Design, July 1851.

adapted to the forms of the various parts, which are slightly wetted, that the rubbing may have the more perfect smoothing effect. Care must be taken, however, not to rub off too much of the whitening, as the beauty of the frame mainly depends on the good body or foundation for the gilding. Glass-paper is also used to give the final polish. The moulding is now ready for a particular sort of size which adapts it for gilding. This size is put on in from four to eight coats, with dryings between. It is a remarkable substance, consisting of pipe-clay, red-chalk, black-lead, suet, and bullock's blood, and is sold to the gilder in a tenacious mass, rather softer than butter. A portion of this gold-size is melted with thin clear size of the ordinary kind, and laid on while barely warm, with a brush, and with great nicety of hand. The best test of good work is to produce the smoothest surface with the least loss of gold-size.

The final processes require several gilding-tools. These are, first, the *cushion*, a flat board, eight inches by six, covered with layers of woollen cloth, or flannel, over which is strained a piece of leather, nailed down tightly to the edges of the wood. Along one of the short sides of the cushion, and reaching round half of each of the two long sides, is a rim or border of parchment, three inches high, as a safeguard to the gold-leaf which is to be laid on the cushion. The other sides are left open, to facilitate the cutting of the said leaf into strips. The *knife*, for cutting gold-leaf, is straight, smooth-edged, but not very sharp, and ends in a well-defined point. The tool for laying on the gold is called a *tip*, and consists of two pieces of card glued together, with the ends of a row of camel-hairs confined between them, the remaining portion of the length of the hairs protruding from the cards to a distance varying from one inch to two inches and a half. Sometimes these cards are circular, and have a little wooden handle springing perpendicularly from the centre.

Gold-leaf is supplied to the gilder in books, twenty-five leaves to each book; and this, with the gilding-tools, being ready, the work proceeds as follows. The gilder takes the cushion, and supports it on his left hand by means of a leather loop underneath; the open end of the cushion being towards the right. He then places the tip, the knife, and a camel's-hair pencil, between the fingers of the left hand, that each may be immediately at hand when required. Thus armed, he may be compared to the oil-painter, with his palette and brushes, all ready for action.

Taking the book of gold-leaf, he has now to convey the required number of leaves for the work he has in hand from the book to the cushion. This requires some care, on account of the fragile nature of the material. It is effected without touching the leaf, simply by the breath. Each leaf is blown gently from its place in the book, on to the cushion, though a learner will occasionally blow wide of the mark. The breath also afterwards assists in raising and spreading one out of the confused heap of leaves on the cushion, and adjusting it in front, where it is to be cut out in strips according to the width of the moulding. In a moulding which has deep depressions, several lays or widths of gold must be used, as a strip of the whole width of the moulding would be torn in fitting it to the hollows, and would exhibit irregular fractures, called by gilders *spider-legs*. According to the width required, therefore, he cuts the sheet into four, three, or two strips. It is seldom that a larger piece than half a leaf is used at once.

A few inches of the moulding about to be gilded are first wetted with water, laid on with a camel's-hair pencil; the moisture not to extend beyond the first lay. The gilder then applies the tip to a slip of gold, which slightly adheres to the hairs; from whence he transfers it steadily to the moulding. When the hairs of the tip fail to take up the gold, they are rubbed between the cheek and the palm of the hand, when the friction brings them into proper action. When the gold is laid on, it is blown forcibly to expel as much of the moisture as possible from underneath it, a dry camel's-hair pencil being used to press down any parts which do not adhere. Another portion is then wetted, and another piece laid on, overlapping the other by about the eighth of an inch. Thus piece by piece, and one width after another, the whole moulding is completed and set aside to dry. There is a particular state of dryness, known only by experienee, when the work is fit for burnishing. The burnishers are either of flint or agate, and they can be rubbed briskly over the gold, not only without injuring it, but to the great increase of its brilliancy. This is owing to the foundation of gold-size and whitening, which forms a yielding substance under the hand; but the burnishers require peculiar handling to be used with the proper effect. They are of various shapes and sizes. When the burnishing is done, attention must be paid to certain parts of the gilding which are to be in dead gold, (called *matt*,) and which have consequently been left unburnished. Over these parts a very thin clear size is passed, and when dry the gold is wiped carefully with soft cotton wool, and any little defects remedied by adding small pieces of gold-leaf. When these are also dry, the whole is completed by wetting with clear finishing-size on the matt parts with a pencil. The moulding is now complete, and passes into the hands of the frame-maker, who cuts it up and joins it in the required manner for the picture; after which the gilder has again to take it in hand to stop up and conceal any nail-holes, and to paint the outside yellow, for it seldom happens that the outside is gilt.

For a richly-ornamented frame, where oil gilding is required, the processes are rather different. The moulding is whitened as before, but it is then made up to the required shape, and is decorated with composition ornaments of a more or less elaborate character. The gilder receiving the frame thus, first washes it to free it from oil. He then gives it two or three general coatings of very thin white, in which a little clay, of a peculiar mellow texture, has been mixed. Further coatings must be given to the parts intended for burnishing. The frame is now ready for *clear-cole*, a moderately strong size, of which two or three coats are laid on. After this comes what is called oil gold-

size, which is a mixture of boiled linseed-oil and ochre, laid on as smoothly as possible with a brush. This oil gold-size being laid on over night, the frame is generally in the proper state on the following morning for gilding. This is effected in the same manner as before, except that no water is used, the partially dried oil answering the same purpose, and the gold is cut into rather differently shaped pieces, according to the inequalities of the ornamented frame. When the ornaments are very deep, the gilding has to be repeated, and the gold pressed in with cotton. The work has at first a ragged and unequal appearance, but is brought into order and regularity by means of a brush, with which every part is carefully gone over, superfluous gold being removed from some parts, and worked into others. To do this well, without scratching or disturbing any portion of the surface, requires considerable skill. The process is called *skewing*, and the particles of gold collected from it, are sold under the name of *skewings*. The clear-cole and oil gold-size are kept carefully away from any parts designed to be burnished, which must be treated as before described. After the frame is skewed and dusted, it is sized with clear size, and yellowed on the outside. The smoothing of elaborate frames is not effected wholly by pieces of stone, but by seal-skin, Dutch rush, and pieces of linen cloth.

In regilding old frames it is usual to wash off the old gold and a portion of the gold-size beneath, to stop up holes with putty, and then to lay on new gold-size, and re-gild. If the frame has been gilt in oil-gold, that cannot be washed off, but must be scoured clean preparatory to the after processes.

For gilding on metal, or water-gilding, see BUTTON. This unhealthy occupation is now nearly superseded by Electro-gilding. See ELECTRO-METALLURGY. The composition of gilding-metal for common jewellery is described under BRASS. The gilding of the leather and of the edges of the leaves of books, is described under BINDING. For the gilding of PORCELAIN, see that article.

GIN, from *Geneva*, or *Genièvre*, the juniper. See DISTILLATION.

GIN, a contraction of *en-gine*. See COTTON.

GINGER (*Amomum zinziber*), a plant, whose roots are valued for their pungent qualities. It appears to be a native of India and China, but succeeds remarkably well in the West Indies, where it was carried at a very early period, and whence the finest ginger is now obtained. It is received in two states—preserved, and dried. In the former, the roots taken up when they are young and full of sap, are scalded till they are tender, then peeled and covered with a thin syrup. From this they are afterwards removed, placed in jars, and a richer syrup poured over them. In this state they reach us, forming one of the most delicious and wholesome of preserves. Dried ginger of the best kind consists of the best roots scraped, washed, and dried in the sun until they are quite white. Inferior roots, scalded in boiling water before drying, are of a dark colour, and obtain an inferior price as black ginger. The domestic uses of ginger are well known. It is considered a good stomachic, and an improver of digestion in languid habits. The consumption of ginger in this country is stated at about 10,000 cwt. per annum.

GIRDER. See CARPENTRY—FLOORS AND PARTITIONS—ROOF. Iron girders are also noticed in BRIDGE, *Section VI.*, and in FIRES—FIRE-PROOFING, page 669.

GLASS. The discovery of glass is one of the great triumphs of the useful arts; for what can be more admirable than that the application of heat to certain widely different materials, all more or less opaque, should produce a homogeneous transparent substance, capable of being moulded under the continued application of heat into every variety of form, and permanently retaining that form when the heat is withdrawn? This discovery was made long before science can be said to have existed, yet it has been of as much importance in assisting the advancement of science as in favouring the progress of civilization.

The use of glass in our windows, instead of the louvre-boards of our ancestors, has introduced comfort into the meanest dwelling which previously did not belong to the richest palace. By means of this contrivance the light is filtered from the wind, the rain, and the cold; we can enjoy the one without being inconvenienced by the others; and we can, in conjunction with our methods of warming, create an in-door climate adapted to our feelings and desires. The use of glass in many of our domestic articles of furniture and vessels contributes to cleanliness and health, for the slightest soil on our glasses and decanters is revealed by this most transparent material, and the purity of the water and other liquids contained in them is physically tested by the same means. Even the mirror, which adorns our rooms, reminds us of the necessary attention to personal appearance, which self-respect as well as respect for society demands. By means of glass the eye of advancing age regains something of its youthful vigour. By means of glass the astronomer makes us acquainted with distant spheres, and the naturalist with the inhabitants of a drop of water. By means of glass the natural philosopher has discovered the physical marvels of the atmosphere; and the chemist, its equally wonderful chemical properties. Indeed, science is greatly indebted for its progress to the transparent chambers of glass of every variety of shape and form so easily and so cheaply procured, within whose transparent walls processes can be isolated and watched without danger to the operator. The whole of pneumatic chemistry depends on glass; as does also the existence of many of the most valuable acids, which could never have been discovered, or if discovered, preserved for any length of time, but for glass retorts and glass bottles.

SECTION I.—HISTORICAL NOTICE.

The honour of this great discovery has been assigned to the Phœnicians. It is stated by Pliny that some mariners who had a cargo of *nitrum* (probably soda) on board, having landed on the banks of the

river Belus, a small stream at the base of Mount Carmel in Palestine, and finding no stones to rest their pots on, placed under them some masses of nitrum, which, being fused by the heat with the sand of the river, produced a liquid transparent stream of glass. It is difficult to imagine how such a result could have been produced under the very moderate heat of an open fire. However this may be, the Sidonians of the neighbourhood are said to have improved upon the discovery, and to have practised the new art with considerable success. It would be much more philosophical to suppose that the discovery of glass originated in the practice of some of the more ancient arts, such as the firing of bricks, or earthen vessels, and the reduction of metals from their ores, in which processes vitrifiable materials exposed to an intense heat, lead to the production of an impure glass, or slag.

Materials for a connected history of glass do not exist; but it appears from the researches of learned men that the art of glass-working was practised in Egypt before the exodus of the children of Israel from that land, 3,500 years ago. Glass-blowers at work are represented on some of the monuments, which are proved by the accompanying hieroglyphics to be as old as that event. *Glazed* pottery was known at the same period; and there has been found at Thebes a glass bead, about $\frac{3}{4}$ inch diameter, of the same specific gravity as our crown glass, on which is inscribed the name of a monarch who lived 1500 B.C. The Egyptians also counterfeited precious stones in glass: they used it for drinking-vessels, for mosaic work, the figures of deities, and even for coffins.

The Jews appear to have carried with them from Egypt a knowledge of the art; and subsequently the Greeks and Romans, who successively conquered Egypt, acquired the art from the same remarkable people, or, at least, discovered among them a source of supply for articles in glass. The glass-houses of Alexandria were celebrated among the ancients for the skill and ingenuity of their workmen. The cinerary vases of greenish glass in the British Museum, which were found in Roman barrows, are supposed to be of Egyptian or Roman manufacture. Glass vessels have been found among the ruins of Herculaneum: and there is evidence that glass was used for admitting light to dwellings in Pompeii. From these, and similar notices of the early history of glass, it is evident that it was during many ages a costly luxury. We must, however, suspect some exaggeration in such statements, as, that Nero paid 6,000 sestertia, or nearly 50,000*l.* sterling, for two cups of clear glass, if such a price is to be taken as a representative of the value of glass at the period in question. The statements of the gossiping Pliny must always be received with caution; but even he does not confirm the above account, but only remarks that in his time the superior kinds of glass were in such extensive use as almost to have superseded cups of the precious metals.

Glass-making in Britain appears to be of ancient date. The Druids are said to have manufactured beads and annulets. Glass vessels were made by the Anglo-Saxons. The *snake-stones* found in Wales are glass beads, which were used by the Druids as a charm: they are usually of a green colour, but some are blue, and others curiously variegated with waves of blue, red, and white. The *aggry-beads* of Ashantee, which are occasionally dug out of the earth, are of great beauty; their variegated strata are "so firmly united, and so imperceptibly blended, that the perfection seems superior to art: some resemble mosaic work; the surfaces of others are covered with flowers and regular patterns, so very minute, and the shades so delicately softened one into the other, and into the ground of the bead, that nothing but the finest touch of the pencil could equal them. The agatized parts disclose flowers and patterns deep in the body of the bead; and thin shafts of opaque colours, running from the centre to the surface." Mr. Bowdich, who thus describes them, thinks it not improbable, "that in the golden age of Egypt she had communication with the Gold Coast; indeed, it has been thought, and perhaps not without some reason, that the Gold Coast is the Ophir of Solomon."

The Chinese, who have been celebrated from ancient times for the manufacture of porcelain, do not seem to have attained any proficiency in the kindred art of glass-making. They are skilful in imitating precious stones in vitreous substances, but even at the present time they do not appear to be acquainted with an economical method of making glass from the raw materials. They are accustomed to import glass from Europe, which they break up, re-melt, and convert into such articles as they require. There is a royal glass-manufactory in Pekin, which is carried on as much for amusement as for profit.

To Venice belongs the honour of first making glass so cheap as to allow of its more general introduction. Her glass-houses on the island of Murano were, during two or three centuries, the only manufactories of drinking-glasses and mirrors; and on their introduction into other countries, she continued to excel the rest of Europe, especially in ornamental kinds of glass. Venice was celebrated for that kind of ornamental glass, the manufacture of which has recently been revived in the form of letter-weights, and named by the French *mille-fiore* glass, in which a number of coloured flowers and glass ornaments are imbedded in a lump of transparent white glass. The Bohemians successfully imitated the Venetians in the manufacture of ornamented glass. The French government was so desirous of introducing the manufacture into France, that in the time of Louis IX. a law was passed allowing none but gentlemen or the sons of nobility to establish a glass-house, or even to work therein. Traces of the gentility of the art which thus originated, were to be found in France not many years ago, and even in England the workmen were accustomed to style themselves "gentlemen glass-blowers." The French artists, who had been instructed by the Venetians, were incorporated by royal charter with many important privileges, and were established by the government at Tourlaville, near Cherbourg,[1] in the

(1) This spot was selected because in position and physical features it resembled, more than any other in France, the Island of

year 1665. The art continued for some years to be almost literally that of *blowing;* but in 1688 the art of *casting* was invented, or rather revived, by Thevart, who, having obtained a patent for his invention for 30 years, established works at Paris for the manufacture of *plate* glass: the works were soon removed to St. Gobain, in the department of the Aisne, which, for more than a century, was the only place on the continent where cast-plates for mirrors could be procured. The invention is said to have been suggested by the accidental breakage of a pot containing melted glass, some of which flowed under a large flag-stone: on removing this, the glass was found in the form of a plate, such as could not be procured by blowing.[1]

The Italians were the first to apply glass to the making of cameos and intaglios.

The first English glass-houses were those of Crutched Friars, London, established in 1557, for the manufacture of window-glass; and Savoy House, in the Strand, established shortly afterwards for the manufacture of flint-glass; but it was not until 1670, in the reign of William III., that the art of making the fine Venetian drinking-glasses, so much in request, was perfected. Three years after this a plate-glass establishment was begun at Lambeth, but another century elapsed before any work of the kind on a large scale was in existence. In 1771 the British Plate-glass Company received its charter, and erected extensive works at Ravenhead, near St. Helen's, in Lancashire, which are still in active operation. The progress of the glass manufacture in England was rapid, in spite of the incubus of the Excise laws under which it laboured until the year 1845, and our white crystal glass, and even our plate-glass, obtained a superiority over that of any other country, the plate-glass of St. Gobain excepted, for this is probably the best in the world. Since the manufacture has been emancipated, the improvements have been important and rapid: glass is every day receiving new forms and new applications; and even the celebrated ornamental glass of Bohemia is now being rivalled by that of England. A clear perception of beauty of form and harmony of colour is beginning to be felt by the public: this will lead to a demand for articles designed under the influence of good taste: competent artists will arise to gratify it, and manufacturers will be eager to employ them. We are sure that progress in art-manufactures depends as much upon the education of the public as on that of the manufacturer. The influence which they exert upon each other is doubtless reciprocal, as all influence is: if the public taste be bad, the choicest products of art-manufacture will not do much to improve it; and the best artist will have to complain of neglect, because he is either before his time or out of his sphere. On the other hand, if the taste of the manufacturer be not at least *equal* to that of his best customers, they will gratify it in foreign markets, instead of employing him.

Murano; and the success of the Venetian glass-houses was partly referred to advantage of position with respect to the prevailing winds, &c. The idea is not altogether futile, for it is still a common remark among glass-blowers, that the annealing furnace works best when the wind blows in the direction from the hottest to the coolest part. They are exposed to loss and difficulty when the wind blows in a reverse direction, and it is found almost impossible to stop out the reverse current.

(1) St. Jerome states that in his time, A. D. 422, glass was melted and cast into plates for windows. About a century later, Paulus Silentiarius notices the windows of the church of St. Sophia, at Constantinople, as being covered with glass.

Section II.—The Materials and Chemistry of Glass.

The term *glass*, in its widest sense, is applied to those mineral substances which liquefy and become transparent or translucent on the application of heat, remain so on cooling, and exhibit in their fracture what is called a *vitreous* lustre. The term is, however, more commonly confined to a few mineral compounds of saline constitution, by which is meant those substances consisting of an acid in combination with a base or metallic oxide. In the case of glass the acid is *silica* or *silicic acid*, and the base a mixture of an alkaline with an earthy base, such as lime, or with the oxide of one of the heavy metals, such as lead.

Silica, silicic acid, or oxide of silicon, consists of 1 equivalent of silicon $= 15$, and 2 of oxygen $= 16$, making 31, the equivalent of silicic acid. Silica exists in great abundance in nature, forming a principal constituent in rocks and stones, and existing in a free state in flint, agate, calcedony, rock crystal, and quartz, the last two being its purest form. Its insolubility in water and most liquids renders its acid character, *viz.* its disposition to unite with alkaline bases, not very obvious. At a red-heat, however, silica acts the part of a powerful acid, and is capable of expelling carbonic acid, muriatic acid, &c., and combining with bases to form solid compounds, or salts, termed *silicates*. Even the continued digestion of silica in an aqueous solution of an alkali, leads to the formation of a silicate; 1 part of anhydrous potash, assisted by the heat of a wind furnace, will bring into fusion 10 parts of silicic acid: by increasing the proportion of potash, a white enamel is obtained: 1 part of anhydrous soda will unite with 12 parts of silica.

The silicates thus formed are soluble in water, and can be decomposed by acids; hence, they are useless as glass. The silicates of the earths, such as silicate of lime, possess the same properties of easy fusibility, solubility, and decomposition as the silicates of the alkalies, but in a less degree. In forming silicate of lime, the strongest heat of a wind furnace is required, and the compound is not *vitreous*, like the alkaline silicates, but *stony*, and slightly translucent, like porcelain. Silicate of alumina requires a very strong heat for its artificial production. Silicates of the metallic oxides are formed without much difficulty. Silicic acid and oxide of lead unite in atomic proportions. Protoxide of iron forms several definite compounds with silicic acid, which are black or dark olive grey in colour. These silicates of the heavy metals are easily attacked by substances possessing a tolerably strong amount of affinity for the base.

Thus it will be seen that no one of the above silicates is adapted of itself to form glass. No single

silicate is transparent, free from colour, fusible at a moderate heat, and insoluble in water. It happens, however, fortunately, that mixtures of different silicates possess all these valuable properties in various degrees. By a judicious mixture, the earthy and metallic silicates lose their opacity and disposition to crystallize, and the alkaline silicates are deprived of their solubility.[1] The temperature at which the combination of two silicates fuses is something intermediate between the high heat required for the earthy silicates and the low temperature at which the metallic silicates fuse, and this intermediate temperature is much more convenient for working.

The silicates which are formed by the hand of art differ in one essential particular from those which exist so abundantly in nature; that is, they are *amorphous*, or non-crystalline in structure. There is, however, one silicate, that of alumina, which has a great tendency to crystallize; but by combining this with some other simple silicate, it becomes amorphous. Most clays are silicates of alumina; felspar is a silicate of alumina and potash; mica is a silicate of alumina and lime.

Potash, or soda, or mixtures of both, are essential ingredients in all the common kinds of glass: the different properties of the various kinds are mainly produced by varying the quality and proportion of the base of the earthy or metallic silicate. Regarding glass as a chemical, and therefore as a definite compound, the various kinds have been distributed in the following manner:—

1. Silicate of potash and oxide of lead. Examples:—*flint, crystal,* and *strass.* Flint contains more lead than crystal, and strass more than flint.

2. Silicate of soda and lime; or, silicate of potash, soda, and lime. Examples:—*common window, English crown,* and *plate.*

3. Silicate of potash and lime. Examples:—*foreign crown, refractory Bohemian glass.*

4. Silicate of soda, lime, alumina, and oxide of iron. Example:—*coarse green wine-bottle glass.*

The silicate of lead imparts brilliancy and fusibility to all silicates infusible by themselves; but an excess of lead gives a yellowish tint. Silicate of lime imparts hardness, as does also silicate of alumina; and the silicate of iron gives the dark colour to common bottle-glass. Potash and soda render glass easy of fusion, especially the former.

(1) This statement is practically true; but, in strictness, even the best made glass is to a certain extent soluble. If finely-powdered window-glass be placed on turmeric paper and moistened with water, it will exhibit an alkaline reaction. Griffiths extracted 7 per cent. of potash from flint-glass powder, by boiling it for weeks together with water, and repeatedly re-grinding and washing it. The action of rain and moisture on window-panes is to wash away the alkali, and expose a very thin layer of silica or of silicate of lime, which often exhibits prismatic colours. Specimens of ancient glass, which have been dug out of the earth, often exhibit a pearly lustre, resulting from pure silica, the alkali having been slowly removed by long exposure to damp.

A *soluble glass* is sometimes made for the purpose of brushing over the woodwork of houses, theatres, &c., in order to render it fire-proof. Such a glass may be made with 70 parts carbonate of potash, 54 carbonate of soda, 152 ground flints or quartzose sand. The solution will penetrate the pores of wood with ease, and leave a vitreous coating.

In mixing the ingredients for making any particular kind of glass, the law of equivalent proportions is not observed. Indeed, there is no kind of glass in common use that is not considerably older than the date of the discovery of this grand law. This is one of those instances, so common in the useful arts, in which success has been attained by empirical means, with no aid from science. It is true that science steps in, and reads a lecture full of instruction to herself on the art of making glass, but scarcely, if at all, benefiting the glass-maker, who still continues to mix his materials according to old recipes, and to preserve his secrets, as he calls them, with jealous care.

The silicic acid is practically represented by fine sea-sand. Flints, calcined and ground, were formerly used, and hence the name of *flint-glass.* The sand consists of minute grains of quartz, rounded by attrition. It is liable to be contaminated with oxide of iron, the presence of which would impart a sensible green tinge to the glass. This oxide of iron might apparently be washed out by means of muriatic acid; but the makers of flint-glass prefer sand which is free from iron, such as the white sand of Alum Bay in the Isle of Wight, the sand of the port of Lynn in Norfolk, the sands of Reigate, Leighton Buzzard, and St. Helen's in Lancashire. Vessels from Sydney and New Holland are freighted back to England, or are ballasted with a fine sand, much prized by the glass-makers. The sand is always cleaned by washing in water; and it is said that the Isle of Wight sand requires about eight waters to cleanse it from chalk and other impurities. After washing, the sand is heated to redness, to burn off vegetable matters: when cold, it is sifted through lawn sieves, to separate the larger grains, pieces of fuel, &c.

Carbonate of potash, or pearlash, is imported for the glass-maker from British America and Russia: it is contaminated with sulphate and muriate of potash, and other impurities. These are separated by dissolving the potash in water, and when the impurities have subsided the lye of refined carbonate of potash is drawn off by a syphon, and evaporated to dryness. Pure carbonate of potash is, however, now manufactured from the alkaline residue of the nitric acid manufacturers, viz. sulphate of potash. The alkali-makers also supply the glass-makers with refined pearlash.

Lead is used either in the form of litharge or of red lead. Red lead (Pb_3O_4) is preferred to litharge, (PbO,) on account of its finer state of division, its pulverulent form, and also because it is decomposed in the glass-pot into ordinary protoxide of lead, and oxygen; the latter, in escaping, serving to oxidise and remove many impurities, such as carbon, which would impart a brownish colour to the glass. Saltpetre is usually added in small quantity, to increase the dose of oxygen, and to assist in driving off the globules of air entangled in the liquid glass.

A few ounces of black oxide of manganese are usually added to the materials for making flint-glass. The presence of manganese assists in clearing the fused mass of colour arising from carbonaceous matters

and protoxide of iron. When the green silicate of the protoxide of iron comes in contact with one of the higher oxides of manganese, it abstracts some of the oxygen of the latter, and becomes converted into silicate of the peroxide of iron, which is almost colourless compared with the silicate of the protoxide. By thus parting with oxygen, the peroxide of manganese becomes reduced to the protoxide, which combines with silicic acid to form a colourless silicate. The carbonaceous matters are also oxidised by the peroxide of manganese, their carbon being converted into carbonic oxide and carbonic acid gases. This cleansing action of manganese has given to it the familiar title of *glass-makers' soap*. It must, however, be used with care, for, if slightly in excess, a lilac or amethyst colour is given to the glass, in consequence of the formation of a compound of silicic acid with sesquioxide of manganese. The remedy for an accident of this kind is to introduce a pole of wood into the coloured mass, and quickly stir it up, when the sesquioxide becomes reduced to the protoxide, and the lilac colour disappears. This operation resembles that of *poling*, described in the article COPPER.[1]

Such is, or rather ought to be, the action of manganese as an ingredient in glass-making. Some manufacturers, however, use it to disguise the bad colour of the other materials, which yield a green glass, *i. e.* a glass which transmits yellow and blue rays, while it stifles or absorbs the red. Now, as the presence of manganese contributes to the formation of a red glass, or one which transmits red rays, and absorbs the yellow and blue, the proportion of the manganese is so artfully contrived that a mixture of two coloured glasses is produced, which mutually disguise each other's defects, so that the green and the red rays combine together in the glass, and thus transmit white light. The plate-glass manufacturer sometimes allows a slight excess of manganese, in order to produce a delicate amethystine tint, which improves the complexion of persons who receive the light of day through a window. This, however, is not the origin of the tinted glass which is to be seen in the windows of some of the houses at the west end of London. By long exposure to the weather and to the action of light, the red manganese glass has in some way, which it is difficult to explain, become isolated from the green, and so far predominates, that a white window-curtain, the roller-blind drawn down, or other light object, allows the red tint to be distinctly seen from the street.

Glass is also liable to other decomposing influences, which are better understood. The glass of stables is peculiarly liable to decomposition and the exhibition of prismatic colours; but this is due to the ammonia attacking the silica. Glass which contains oxide of lead is liable to blacken on being exposed to air containing sulphuretted hydrogen; and such glass, on being heated, is liable to become black, by the reduction of the oxide to metallic lead. The action of hydrofluoric acid on glass has been noticed in the article FLUORINE.

(1) Arsenious acid (AsO_3) produces the same result, taking up oxygen and becoming arsenic acid (AsO_5).

Glass is also liable to change from what is called *devitrification*. Réaumur noticed that glass vessels buried in a crucible containing a mixture of gypsum and fine sand, and thus exposed to the high temperature of an earthenware furnace, during the burning, were deprived of their lustre and much of their transparency; the fracture was dull and earthy, but at the same time fibrous, and of a silky texture: a portion of unchanged transparent glass was generally left in the middle, towards which the fibres converged. In an analysis by Dumas of devitrified glass, a great loss of potash was noticed. Comparative analyses have shown that in a mass of such glass different chemical compounds are formed, one of which assumes the crystalline form. The devitrified state may also occur during the operations of working, in consequence of repeated heating: certain parts of the mass become opaque, and the glass too tough to be worked. The brittleness of glass, and its liability to break from sudden changes of temperature, are greatly diminished by devitrification: such glass is even less brittle than porcelain. *Réaumur's porcelain* is made of this kind of glass.

An intelligent manufacturer[2] (to whom the art is greatly indebted for a variety of improvements, and the scientific inquirer for access to the best sources of information connected with flint-glass,) arranges the various glasses known in commerce into two groups, *simple* and *compound*. Simple glasses are,—I. *Crown-glass*, which may consist of sand 5 measures, ground chalk 2, carbonate of soda 1 measure, and sulphate of soda 1. II. *Plate-glass*, which may consist of Lynn sand, washed and burnt, 400 lbs., carbonate of soda 250 lbs., ground chalk 30 lbs. III. *Common bottle-glass:* sand 100 measures, soapers' waste 80, gas-lime 80, common clay 5, rock-salt 3. Compound glasses, in addition to the above ingredients, contain certain metallic substances, in various proportions. Thus, white enamel contains arsenic, tin, or antimony, which, as well as lead, form distinct qualities of compound glasses, materially increasing their specific gravity, and acting as powerful fluxes. The metallic oxides also impart colours to glass. A highly pellucid and transparent flint-glass may be composed of the following ingredients:—carbonate of potash 1 cwt., red lead or litharge 2 cwt., sand, washed and burnt, 3 cwt., saltpetre 14 lbs. to 28 lbs., oxide of manganese 4 oz. to 12 oz. The mixtures of these materials is called *batch*, and when fused, *metal*.

Soft white enamel (opaque). To 6 cwt. of batch add 24 lbs. of arsenic, 6 lbs. of antimony.

Hard white enamel (opaque). To 6 cwt. of batch add 200 lbs. of putty prepared from tin and lead.

Blue Transparent glass. To 6 cwt. of batch add 2 lbs. of oxide of cobalt.

Azure Blue. To 6 cwt. of batch add about 6 lbs. of oxide of copper.

Ruby Red. To 6 cwt. of batch add 4 oz. of oxide of gold.

Amethyst or Purple. To 6 cwt. of batch add 20 lbs. of oxide of manganese.

(2) Apsley Pellatt: "Curiosities of Glass-making." 1849.

Common Orange. To 6 cwt. of batch add 12 lbs. of iron ore and 4 lbs. of manganese.

Emerald Green. To 6 cwt. of batch add 12 lbs. of copper scales and 12 lbs. of iron ore.

Gold Topaz Colour. To 6 cwt. of batch add 3 lbs. of oxide of uranium.

Cullet, or broken glass, may be mixed with the batch of the above glasses in suitable proportions.

The specific gravity of the different kinds of glass varies from 2·4 to 4. Flint is the densest kind of glass, on account of the large proportion of lead in it; its specific gravity varies from 3·2 to 4; plate-glass from 2·4 to 2·6.

Section III.—The Glass Pots, Furnace, &c.

It will be seen from the above details, that the base of all glass is sand, and that an alkali is the chief solvent. In the compound glasses, oxide of lead as well as the colouring metals behave as active fluxes; such glasses, therefore, need less alkali in proportion to the sand than the simple glasses. In fusing the materials of which they are composed, and retaining them in a state of fusion, flint and compound glasses require protection from the smoke and flame, which would deoxidize the lead and other metals, and precipitate them in the metallic state; hence these glasses are melted in covered or hooded pots, sheltered entirely from the fire. Flint glass requires less heat for fusion than plate or any of the simple glasses; but the heat having to find its way through the solid walls of these glass-pots, the temperature of the flint-glass furnace is higher than would be otherwise necessary. On the Continent, where dried beech or oak fuel is burnt, open pots can be used for flint-glass. The simple glasses, *crown*, *plate*, and *bottle*, could not be melted in a covered pot. The intense heat necessary for the fusion of these requires that the flame of the furnace should come in contact with the materials, so that open pots are used in melting them.

The *batch* or *frit* is prepared by carefully mixing the materials and sifting them through coarse sieves. It is of a salmon colour. The mixing is usually performed by hand, and is therefore imperfect, a circumstance which is likely to interfere with those chemical changes and mutual reactions of the materials which lead to the formation of a homogeneous fluid transparent body. A mixing apparatus has been contrived by Mr. Chance, for crown-glass, consisting of a chamber *a*, Fig. 1052, with an opening *b* at the top

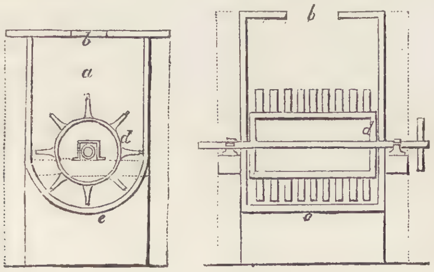


Fig. 1052.

for receiving the materials, and another in the semicircular bottom, at *c*, through which the batch is removed; *d* is a cylinder on the surface of which a number of beaters are obliquely fixed. Motion is given to the cylinder, which tosses about and mixes the materials. In some cases a revolving wooden barrel is used, and is said to be the most effectual mechanical method hitherto adopted.

The flint-glass-house is usually in the form of a truncated cone 60 or 80 feet high, and 40 or 50 feet in diameter at the base. In the centre of this is the furnace, which is circular in form, and in its action is intermediate between an air-furnace and an oven: round its circumference at regular intervals are the pots in which the glass is melted, and these vary from 4 to 10 in number. The grate is nearly on a level with the floor; the ash-pit, or *cave*, is a subterranean passage extending across the building, and at right angles with it are smaller caves communicating, so as to catch the wind from as many aspects as possible. There are as many flues as pots, one flue being placed between every two pots, and immediately abreast of each pot and between two flues is an aperture called the working hole, which is used for introducing the raw materials and getting out the glass. The arrangement of the furnace will be understood from the plan Fig. 1053. The coals are shovelled through a

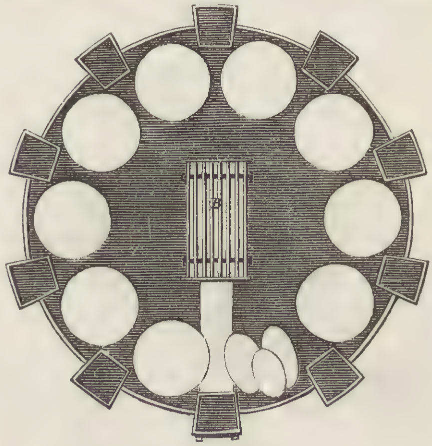


Fig. 1053. GROUND-PLAN OF THE SIEGE, FLUES, AND FIRE-PLACE OF FURNACE.

square hole A upon the grate in the centre of the furnace B: the grate bars are supported by two strong iron sleepers, and are protected from the intense heat by being previously covered with a layer of clinkers, potsherds, or broken Welsh lumps; but as the furnace attains its maximum heat, sufficient clinkers are formed to serve the purpose. A furnace for 10 pots of 36 inches diameter is 12 feet 7 inches in interior diameter; 19 feet in exterior diameter, including the flues: the height to the inside centre of the dome D is 4½ feet; each of the arches is 3 feet 1 inch wide by 3 feet 3½ inches to the highest part. The flame or smoke is not allowed to issue from the centre, it therefore escapes by the linnet holes C, below the foot of the dome, Fig. 1054, and passing up the flues F discharges into the brick dome and from thence into the funnel and chimney shaft. The fire is regulated by the *tiseur*, who can raise the heat of

the furnace to the highest pitch by opening holes at the bottom of the grate. A ten-pot furnace consumes from 18 to 24 tons of coal per week. In

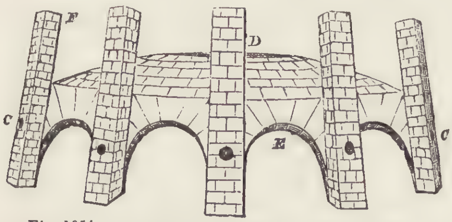


Fig. 1054 INTERIOR VIEW OF THE BRICK DOME.

addition to the principal furnace, there is also opening into the glass-house the end of a long gallery called the *leer* or annealing arch, Fig. 1066, in which the manufactured goods are allowed to cool gradually. There is also a small furnace for softening the glass during the fabrication of a vessel when too large to be heated before one of the working holes. In Mr. Pellatt's glass-house, the interior of which is shown in Fig. 1055, the pots are arranged differently to those in the plan, Fig. 1053; for instead of one large furnace, he has two small ones, both opening into the same chimney, so that while one is in full operation, the other may be undergoing repair, or not be worked at all should the trade not be brisk. This arrangement leads to considerable economy of fuel.

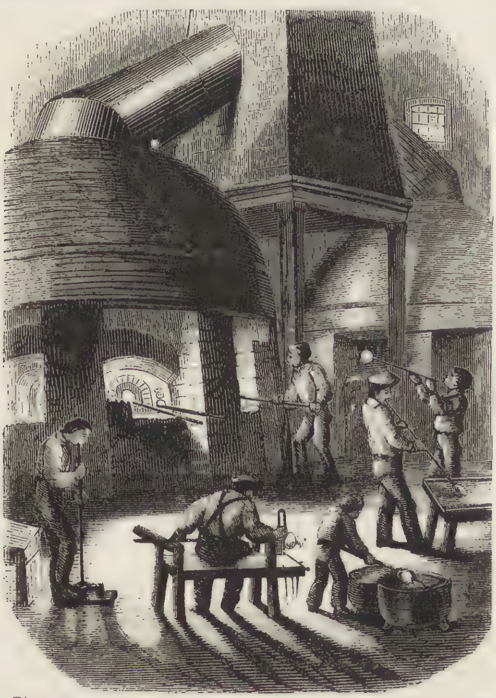
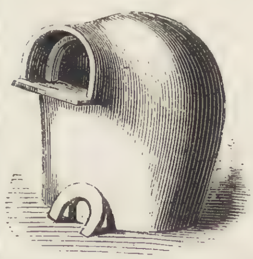


Fig. 1055. ELEVATION OF THE FURNACE AND INTERIOR OF FLINT-GLASS-HOUSE.

The pots for flint-glass are hooded, and have a mouth in front. They are made of fine, pure refractory clay, free from lime and iron pyrites, and containing as little oxide of iron as possible. Stourbridge clay, which contains little besides silicic acid and alumina, is well adapted for the purpose. About one-fifth of old pots ground is used with the clay: this assists the more regular drying of the pots, and renders the whole body more porous and less likely to crack by heat. The pots are built without the use of moulds. The old and new clay are mixed together, saturated with water, and kneaded by the feet of men three times over, until the mass has acquired a pasty consistence. It is then rolled into small pieces about the size of a sausage, and these wet rolls are placed together upon a leaden slab to the thickness of 4 inches to form the bottom; the mass is then beaten with a wooden mallet, and pressed by hand. The sides are raised by pressing the clay rolls from the inside of the curve, upon the rolls previously applied, so as to exclude the air and leave the substance of the sides from 2½ to 3 inches thick. The dome is continued in the same manner, circle upon circle, diminishing towards the centre. When the pot thus formed is sufficiently hard, the mouth is cut open and finished. Experience has proved that kneading by the naked feet is better than by a pug-mill or machinery. The clay is kneaded in a room of uniform temperature, not below 55°, nor above 80°, as it is not desirable to dry the pots too quickly. The pots are left to dry or ripen from 4 to 6 months. When sufficiently dry, they are removed to a hot room of from 100° to 150°. Before setting in the furnace a pot is annealed in the arch, where it is kept for a week or more, and gradually raised to a white heat. The flint-glass pots, Fig. 1056, will contain about 18 cwt. of melted glass: they measure 3 feet external diameter;



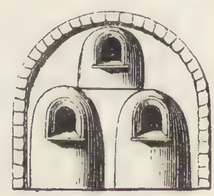


Fig. 1056. FLINT-GLASS POT. *Fig.* 1057. COLOURED GLASS POTS.

they are 3 feet high to the filling part, and weigh about 10 cwt. The horse-shoe-formed piece shown in Fig. 1056 is used for contracting the mouth of the pot. For coloured glass, 3 small pots, 2 side by side and 1 above, as in Fig. 1057, are used in melting, and the 3 fill up the same space in the furnace as that occupied by one large pot.

The setting of a new pot is a very arduous undertaking. It is generally performed at the end of the week, when the work of the glass-house is slackened. All hands are required to be present, absentees, except from illness, being fined severely. The Editor witnessed the operation a few years ago, and described it in his work on the Useful Arts: the following, with a few additional particulars, is taken therefrom. The first part of the process was to get out the old pot, which had done duty for seven months, but was now rendered worthless from having "sprung a leak." The heat of the glass-furnace is sufficiently intense to an unpractised looker-on, during the ordinary operations of glass-blowing, &c., when the fire is

covered up by badly conducting materials, with the exception of a few apertures for getting out the glass and heating the tools, &c.; but now the wall of one of the arches was to be taken down, thus exposing the men to the naked heat of a huge furnace. The men were about 24 in number, 2 or 3 of whom worked at a time, and were frequently relieved.

The difficulty of getting out the old pot was very great, owing to the firm hold which it had on the floor of the furnace: it was in fact cemented to its *siege* by the glass which escaped from the crack whereby it was rendered useless; and this cementing glass became more and more difficult to loosen, as the current of air which rushed towards the now large opening solidified the glass. The men, therefore, had to work at the bottom of the crucible with a large iron bar, steeled and sharpened at the point, placed across another bar or roller as a fulcrum, and resting their weight at the end of this long lever endeavoured to loosen the pot. Six or eight other men were also furnished each with a bar about 5 feet long, like a javelin, steeled and sharpened at one end; these rushed forward, guarding their faces with their upraised arms, and aimed a blow at the rocky incrustations on the siege. By such means large pieces of glass, soiled and blackened by the ashes of the furnace, were brought away, together with fire-brick, masses of clay, and sometimes pieces of the pot itself. The men who worked the large bar gave a few blows, and then retreated from the fierce heat, to be succeeded by two or three others, who in like manner performed their brief but arduous task, and then retreated to the shelter furnished by the massive wall of the furnace.

At length, the pot being loosened all round, its base was elevated by crowbars, and a low iron truck moving on two wheels thrust under it, and thus it was withdrawn and thrown aside at some distance. The floods of heat which now radiated from the opening were terrible: before this, the side of the pot nearest the opening, by its contact with the air, had cooled somewhat, and served, to some extent, to keep off the full glare of the furnace; but now there was no shield—no defence. And here was, perhaps, the most arduous part of the operation; the siege, or platform, slightly raised above the floor of the furnace, was to be repaired to receive the new pot; for this purpose, the most fire-proof workman was selected: he was furnished with a kind of shovel, with a handle 14 or 15 feet long resting on the roller before noticed; a number of men stood by, each holding a lump of kneaded fire-clay; one of these men, as he was directed by the foreman, went up to the mouth of the opening, and placing his lump of clay on the shovel, quickly retreated; the clay was then deposited on the siege, and worked quickly with the spade; a second man advanced with a second lump, which in its turn was made to fill up some irregularity in the siege, and thus piece after piece was deposited, until a tolerably even bed was produced. Meanwhile, another party of men were ready with the iron truck at the annealing oven, the doors of which were at a given signal thrown open, showing the pot glowing at a bright red heat. To thrust the projecting bars of the truck into the mouth of the new pot and bring it out, was the work of a moment: it was quickly wheeled to the furnace, deposited in its place, and being held by crowbars, the truck was removed, the whole being accomplished with a dexterous celerity which pleased and satisfied the looker-on. The next part of the operation was to close up the opening, for which purpose two heated masks of fire-clay were brought on shovels: these rose from the ground about a yard high, and upon them were placed bricks and fire-clay. The mouth of the pot being stopped with a temporary screen of clay, the rest of the opening was closed up with great despatch by a number of men, each bearing a portion of clay, or a brick, which he knew precisely where to deposit. The operation thus concluded occupies three or four hours, and is one of great fatigue, excitement, and even danger. The necessity for this operation may not occur for months, but when it does, not more than two pots can be set in the same week, for if more were attempted, the furnace would get too cold, and endanger the setting of the glass in the other pots. Good pots last about three months each; some will last above twelve months, but they wear thin at the back, and endanger the loss of the glass by bursting. The pots are occasionally patched up with clay in front, in the crown, and sometimes at the bottom. When they crack in front, a leak is prevented for several weeks by exposing the crack to the air, and as the glass oozes out, it solidifies and stops it up; or cold water is thrown on it for the same purpose, or a piece of black glass, or of bottle metal, is softened by heat, and plastered on.

The new pot, having safely passed through all this severe treatment, has to undergo a still more serious test. "Will it hold glass?" is the anxious inquiry of the manufacturer. *Cullet*, or broken glass, is first thrown in, and spread over the sides in a melted state; this forms a vitreous glaze, which penetrates to the depth of a few lines into the substance of the pot, and forms a hard glass difficult of fusion, which protects the pot from the further action of the materials.

The raw materials, thoroughly incorporated with from one-fourth to one-third of their weight of broken flint glass, are introduced by means of a clean iron shovel into the melting-pot, which has been raised to a white heat. The pot is filled, the temperature is raised to its maximum, and as the mass subsides by melting, a fresh quantity is introduced, until it is filled with melted glass. The mouth is then closed with a stopper, and luted, leaving only a small aperture at bottom. The glass does not become transparent for some time, the opacity being due to the lime and earthy impurities which do not fuse. The heavier of these subside, but the greater part rise as a scum, called *glass-gall*, or *sandiver*, which is skimmed off through the aperture: if not removed, it would pass off in a dense vapour, which would injure the dome of the pot. It should, however, be remarked, that in flint-glass works the materials selected are so pure,

and in such good proportion, that there is little or no impurity to be removed; and if an excess of one material be found, it is corrected in the next batch. During the melting, or *founding*, the stoker, or *teazer*, keeps the furnace well supplied with fuel, to prevent any part of the grate being uncovered, as a rush of cold air from the cave would probably split the pots. The founders (Fr. *fondeur*) watch the progress of the fusion by taking proofs, or drops, from the pots on a short rod, flattened at one end, and they examine whether any grains of sand remain undissolved, and whether the air-bubbles (called *seed*) have disappeared. During the *boil*, or escape of carbonic acid, the mass is in a state of agitation, which greatly facilitates the escape of air, and answers the purpose of stirring. In 40, or 48 hours after charging, the vitrification is complete. When the sandiver becomes transparent and colourless, the temperature of the pot is lowered by diminishing the draught, in order to bring the glass from a state of perfect fluidity, in which it could not be worked, to that free plastic condition necessary for working. But as the working-heat of the furnace must be constantly maintained night and day, the arrangements of the glass-house are generally so contrived, that the pots shall contain enough metal to last out the first four working-days of the week; the men working incessantly night and day in gangs, relieving each other every six hours. By Friday morning, or evening, the pots are so far emptied, as to require re-filling; or a new pot is to be set, as already noticed.

Section IV.—Flint-Glass.

In the working of flint-glass we see the peculiar properties of this most beautiful material strikingly developed by heat, such as its extreme plasticity, ductility, and flexibility, so that it can be blown, moulded, turned, and cut with scissors into every variety of form. It may be blown so thin as to float about in the air, and its ductility is such that a small lump can be drawn into a thread several hundred feet in length in one minute. The fine filaments of spun glass have been interwoven with silk and other fabrics, with beautiful effect. At common temperatures, glass possesses but a small range of elasticity, but according to Mr. Pellatt, hollow glass balls are so elastic, that if dropped from a height of ten or twelve feet upon a solid polished anvil, they will rebound to half or one-third of that height, and generally without fracture, until after the second rebound. In the ordinary state, glass is not malleable, nor do any vitrified bodies appear to be so.

The property of welding by contact at a red heat or thereabouts, is also one of the valuable properties of glass, whereby it enables parts to be joined together by mere contact, and handles, feet, rings, &c. to be attached. The welding is perfect at the points of union, unless, indeed, a sulphurous or carbonaceous film interpose, and this, however thin, will cause the cohesion to fail.

The property of glass to fracture under the contraction caused by a sudden chill, enables the glass-blower to separate pieces of glass with ease and expedition. The two operations of welding by contact and separation by contraction, are the most important in the manipulations of the glass-blower. The tools used by him are few and simple, and have continued in use, unaltered, for more than 200 years; his tact and skill more than supply the place of mechanical aids. The *blowing-tube* is of iron, from 4 to 5 feet in length, with a bore of from ½ to an inch in diameter. It is smaller at the mouth end than at the other end, which gathers the metal. The *ponty* or *pontil* is a solid rod, used to support the glass while working, when the blowing-rod is no longer needed. Both these rods are heavy or light, according to the nature of the work. The *pucellas*, B, Fig. 1058, made

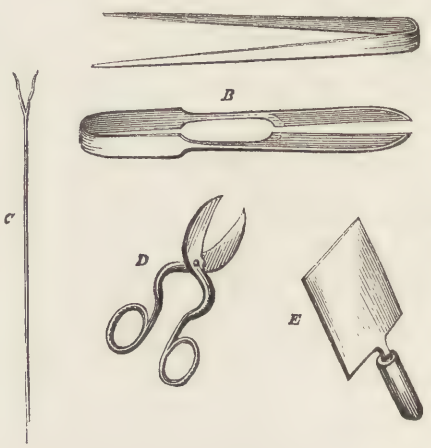


Fig. 1058.

something like a pair of spring sugar-tongs, the prongs resembling the cutting parts of shears, but blunt, are used for rubbing the outside of solid or hollow glass, and pressing it into a smaller diameter, at the same time elongating the parts by rotation. This tool is also used to open or close the insides of hollow vessels, and to shape the glass as it is rotated on the inclined planes of the chair in which the workman sits. The *spring-tool* A is a species of tongs for laying hold of half-formed handles, and for seizing the glass while making. The *shears* D are strong scissors for cutting off the surplusage of glass handles, and for levelling the edges of bowls of wine-glasses, &c. "Much skill is required to shear a wine-glass. It is held upon the iron by the left hand, and rotated towards the shears, which are grasped in the right hand of the workman. A well-skilled workman can shear a glass entirely round the bowl at one operation. In Bohemia and Germany, generally, the workmen are said not to be sufficiently skilful to use the shears; but the edges of bowls are blown in the rough, and cut smooth by the glass-cutter when cold, which leaves a flat and unsightly finish, far inferior to the round smoothed edge of fire-polish after shearing." The *battledore* E of wood is used for flatting glass, as will be explained presently. The glass-blower is also furnished with *compasses* and a *measure-stick*. The *marver* [1] is a slab of cast-iron about an inch thick,

(1) From the French *marbre*, a *marble* slab being formerly used

with a polished surface, supported by a wooden stand. Upon this slab the glass is rolled to give it a regular exterior surface, so that on expanding it by blowing, a

Fig. 1059. THE GLASS-MAKER'S CHAIR.

uniform thickness is produced. The *glass-maker's chair*, Fig. 1059, is a flat seat of wood about 10 inches wide, each end of which is fixed to a frame connected with four legs and two inclined arms, upon which is screwed an edging of wrought-iron for rolling the blowing-iron with the hot glass backwards and forwards with the left hand, while the pucellas, held in the right hand, give the glass the required form. The finishing and intermediate shaping depend chiefly on the application of centrifugal force by rapid hand rotation with the blowing-iron, and upon the expansive force of air in widening the forms while being reheated at the aperture of the furnace, technically called *flashing*, and upon a skilful final throw.

A visit to a glass-house will convey a much more vivid idea of the beautiful art of the glass-blower, and admiration for the wonderful material with which he works, than the most elaborate written and pictorial descriptions. In the absence of this, the following examples from Mr. Pellatt's work may be of use. The first will explain the method of manufacturing a goblet, and nearly all vases or articles having three pieces, viz. a bowl, a stem, and a foot.

The blowing-iron being heated, at the end, nearly to redness, is introduced into the pot of metal, which instantly adheres to it, and by turning it round, the workman can *gather* up as much metal as he requires. If a large quantity be wanted, the first gathering is taken out and cooled by exposure to the air, and when the lump is somewhat consolidated, another gathering is made upon it, and even a third, or a fourth if required. These gatherings increase in cubical proportions, the first being usually about 8 ounces, the second 4 lbs., and the third 16 lbs. For a wine-glass, however, a first small gathering suffices, and this is represented in *a*, Fig. 1060, in the form of a ball of hot glass adhering to the blowing-tube. This having been rolled on the marver, and expanded a little by blowing, assumes the form of *b*, which being further shaped for the bowl of the wine-glass, and flattened with the battledore, is brought into the form of *c*. A solid ball is then attached to the flat part of the bowl, as shown in *d*, and from this the stem is to be lathed or shaped by the pucellas while it is being rotated up and down on the inclined planes of the glass-maker's chair, which serves as a lathe. The stem thus shaped, as at *e*, is ready to receive the foot. The moment the glass gets hard by cooling, the rubbing of the pucellas must be discontinued, or an excoriated surface will result. *f* has a globe attached to the stem, which is afterwards opened, and flattened by the pucellas into a foot, while being lathed and rapidly rotated, as *g*, on the arms of the chair. A boy now gathers a small knob of glass upon an iron pontil, and attaches it to the foot, as at *h*. The blowing-iron is then wetted off at the dotted line in *h* by the touch of the cold pucellas, which cracks the glass, and it is disengaged by a smart blow of the pucellas. In *i* the bowl is under the operation of shearing, so as to make it perfectly even, and fit for the flashing and finishing. The finished glass *k* is then knocked off from the end of the pontil by a sharp blow, and carried by a boy to the annealing arch, on the end of the forked rod c, Fig. 1058.

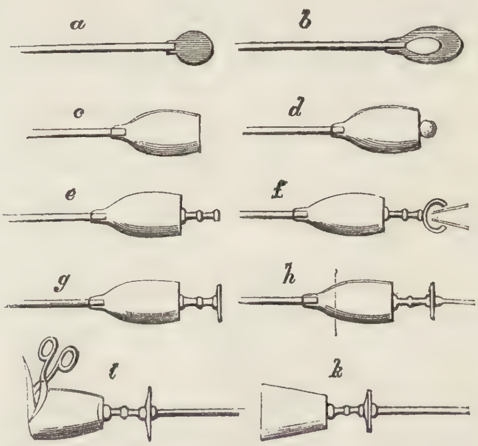


Fig. 1060.

A ringed decanter is made in the following manner: The gathering is shown at *a*, Fig. 1061; this being

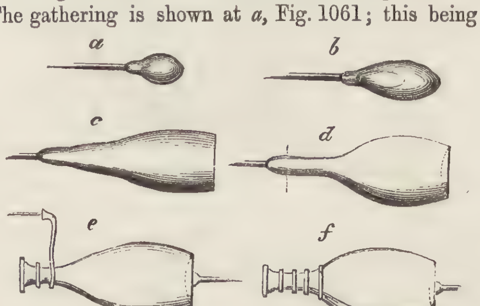


Fig. 1061.

slightly distended, the workman swings the blowing-iron wholly or partly round, and the glass yielding to the centrifugal force, assumes the form of *b*. It is further expanded and battledored at the end, as shown at *c*; it is next formed into *d*. The pontil is then attached to the bottom, *e*; the blowing iron

wetted off at the dotted line, and the mouth warmed up and shaped. Another workman then gathers upon a pontil a small piece of glass, which is dropped on to the part where a ring is required, as at *f*. By rotating the decanter, the entire circle or ring becomes welded by contact, and its surplus is tapered, and torn suddenly away. The whole is re-heated, and the pucellas are then pressed upon the ring of the decanter, while rotating upon the inclined plane of the chair. Pucellas for forming rings differ from the common tools in having two dies affixed to the prongs, which being pressed upon the ring while hot, give the required shape and size after re-heating the decanter. A second and a third ring are then added, as at *f*. The ponty is next rotated on the incline, and the brim finished: the rings are also well melted in to ensure safe welding and annealing.

Flint-glass bottles are formed by moulding. The mould is made of brass. That represented in Fig. 1062 is termed an *open and shut mould*, and is generally constructed in two exact halves, connected with a bottom hinge. This form of mould produces in a round bottle two seams or lines, caused by the two sides of the mould not shutting quite closely. The seam is not unsightly in the square form, as the joint falls into two of the angles; the mould being separated in the line of the diagonal. The following is the process for making eight-ounce phials. The man collects upon the end of his blowing-iron a quantity of melted glass sufficient for one bottle; then, holding the rod vertically for a moment, he gives it a slight jerk, the effect of which is to lengthen out the lump. He then marvers it, pinches the upper part with pliers to form the neck, and placing the hot glass in a brass mould formed in two halves, (which are kept open by a spring,) he pulls the two halves together with a string, as in the figure; then blowing down the tube, the plastic glass forms, as it were, a thin lining to the mould, and assumes its internal form. On relaxing the string, the mould falls asunder, and the phial is taken out adhering to the tube. It is wetted off, and taken up on the end of a pontil by another workman, who softens it in the flame issuing from a hole in the furnace. At Mr. Pellatt's works, a small separate furnace, called the *little go*, is used for this purpose. The workman finishes it off with great rapidity; when it is conveyed to the annealing oven. The mould must be kept hot during the operation, for which purpose two blowers usually work with one mould, one man collecting and marvering his glass, while the other is engaged in blowing it out.

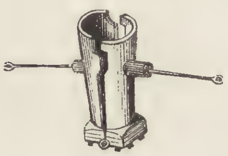


Fig. 1062.

Fig. 1063. MOULDING BOTTLES AND MARVERING.

The seam down the body is avoided by the use of an improved mould, invented by Mr. Pellatt. The body of this mould, c, Fig. 1064, is in one piece, the neck *n n* in two pieces, which, of course, produce two slight seams. These two pieces are kept open by a spring, *s*. When the expanded ball of metal at the end of the blowing-iron is placed in the body, the two halves of the neck are brought together by the guide *g*, connected with the treadle *t*, which is pressed down by the foot. The man then blows down the tube, and on raising his foot, the counterweight *w* falls down: the two neck-pieces fly open, and the bottle is taken out.

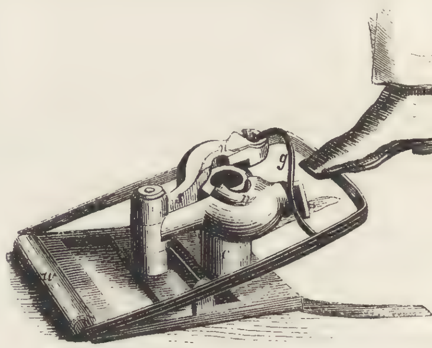


Fig. 1064. BOTTLE-MOULD.

Annealing. Referring to our article ANNEALING for the theory of this curious process, we need only here remark, that the particles of melted glass in a fluid state, exhibit a tendency to arrange themselves in a regular manner, so as to form crystals. When the glass is quickly cooled, no time is allowed to the the semifluid mass to follow this tendency, and the particles are forced to remain in that relative position towards each other which they assume during the working; or in other words, the particles are forced to form an amorphous mass. This forced relative position of the particles is greatest when the glass has been rapidly cooled; but the interior of the mass is not so subject to it as the surface, which also contracts in a greater degree. The outer layers are therefore in a state of tension compared with the interior; and this want of uniformity in the attractions of the particles for each other, causes the force of cohesion in the mass to be destroyed by a slight external impulse. This strained or forced condition

of the particles is relieved by subjecting them to a temperature sufficient to allow them mutually to re-adjust their relative positions, and to fix them in what

Fig. 1065. THE ANNEALING-ARCH.

may be called a natural amorphous state, by gradually letting down the temperature. For this purpose, the glass articles, as they are shaped and finished by the blower, are put into a *lear* at the receiving end or side nearest the glass-furnace, where the temperature is just short of the melting heat of glass. Small articles are arranged in iron trays, which are gradually pushed forward by the trays last put in towards the discharging or cooler end of the furnace, which terminates in the chimney. The lear consists of from two to four cylindrical arches placed side by side.

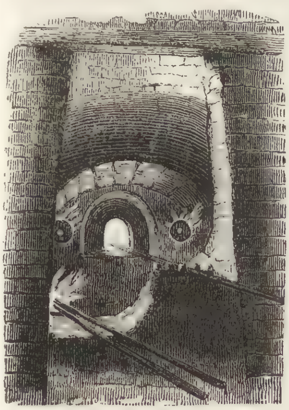


Fig. 1066. THE GLORY-HOLE.

Coke is the fuel, and the annealing lasts from 6 to 60 hours, according to the weight of the articles. The hotter the goods enter the arch, the better. Large goods receive a final re-heating at the mouth of an empty pot called the *glory hole.* The proper direction of the wind is a point of importance. It ought to pass from the fuel of the lear towards the chimney; a contrary current causing much loss from breakage. Goods for cutting require extra care and time in the lear. They may be protected from the cold draught by iron covers called *omnibuses,* or by being buried in sand. In some cases thick glasses are annealed in kilns, *i. e.* spaces entirely shut up, and heated, so that there is no draught or circulation of air within. The lear is furnished with cast-iron doors for opening or contracting the mouth.

Articles in flint-glass may be cheaply and rapidly formed by an operation called *pressing;* for which purpose a die is secured by a ring and handle, and the glass being gathered and dropped into it, a matrix or plunger is brought down by a lever, and presses the soft glass into the required form of the article. The great difficulty is to gather the exact quantity of metal; for if it be in excess, the article is thickened; if not enough to fill the mould, the article is spoiled. In order to get a polished surface on pressed glass, the moulds must be kept at an equable temperature, a little short of red heat. If too hot, the outer die will adhere to the glass: if not hot enough, the surface will not be clear and transparent. Drops for chandeliers are *pinched* in twin brass dies attached to handles, as in Fig. 1067. The dies are pro-

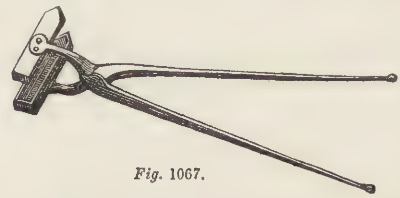


Fig. 1067.

vided with steel wires, which pierce the holes for the brass wires by which the glass drops are united to form the chandelier. Lumps of glass made expressly for drop-pinching, when softened in a blast-furnace, can thus be moulded. Arms of chandeliers are also pressed by twin dies, the upper die being fixed to the plunger, and the under one to the bed of a powerful lever press, the metal being gathered as usual, and the power of the press applied. By this method the crude form only is given to arms and drops. They require cutting and polishing on a lead lap, to produce the required brilliancy.

In the Great Exhibition were chandeliers with ruby drops, and others with drops of different colours. Never was there a greater mistake in art manufacture, than to lower by any means the diamond brilliancy of the brightest and purest flint-glass; for where the light passes through a coloured medium,

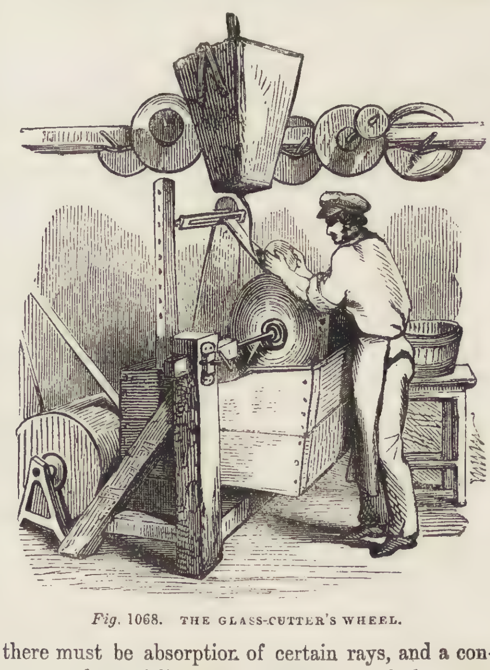


Fig. 1068. THE GLASS-CUTTER'S WHEEL.

there must be absorption of certain rays, and a consequent loss of light and brilliancy. We have not

seen the coloured chandeliers lighted up by night, but we have no doubt that they look much better by daylight; whereas the contrary ought to be the case.

Glass-cutting, or grinding, is performed in the following manner. A cast-iron wheel is made to revolve in a lathe, and above it is suspended a hopper containing sand and water, which continually pours in a thin stream upon the rim of the wheel. On applying the glass to this rim, it is ground away by the action of the wet sand. The rough sand-marks are smoothed out by a stone wheel with water, which prepares it for polishing; this is effected by means of a willow-wood wheel, first with a mixture of pumice and rottenstone, and the finishing is performed by the same wood wheel or lap with putty-powder. Engraving on glass is performed in the same manner as SEAL ENGRAVING. Glass may be drilled or turned on a small scale simply by using oil of turpentine with the common drill, file or turning-tool. If care be taken that the cutting edge is never left dry, it will not soon blunt, and the glass can be worked with great expedition.

Among the varieties of flint-glass, may be mentioned *Strass*, (so called from the name of its German inventor,) used in the manufacture of fictitous gems. It has a remarkable lustre; it contains more oxide of lead than flint-glass, and in some cases a small proportion of borax. Rock crystal is used instead of sand for somevarieties of strass, and for those glasses which are employed as pigments by glass-painters. The materials for strass must be very pure, and when well made, it is a successful imitation of the diamond. The addition of metallic oxides gives various imitations of precious stones. In the French department of the Great Exhibition, some of these were so successful as not to be distinguished from real gems, and no less an authority than M. Bontemps declares that their inferiority consists only in their comparative softness and consequent deterioration by wear. In the English department, Mr. Pellatt, among his other admirable illustrations of the manufacture, had a model of the *koh-i-noor*, made of a highly refractive and dispersive strass, rivalling the diamond itself. Being mounted so as to resemble the original, this model forms an elegant drawing-room ornament.

According to M. Donalt Wieland, an excellent strass may be obtained by one of the following recipes:—

	No. I.	No. II.
Rock-crystal, ground	4056 grains.	3456 grains.
Red lead	6300 ...	5328 ...
Pure carbonate of potash..	2154 ...	1944 ...
Borax	276 ...	216 ...
Arsenic	12 ...	6 ...
	No. III.	**No. IV.**
Fine white sand	— grains.	3600 grains.
Rock-crystal, ground	3600 ...	—
Pure white lead	8508 ...	8508 ...
Pure carbonate of potash..	1260 ...	1260 ...
Borax	360 ...	360 ...
Arsenic.	12 ...	—

The lustre and density of the glass are increased by a tranquil and prolonged fusion, which should be continued for 24 hours.

SECTION V.—OPTICAL GLASS.

The progress of the beautiful science of optics has been to a certain extent impeded by the defects of the flint-glass used in certain instruments. Science requires a perfectly homogeneous glass, of the same density and composition throughout its mass. This it is very difficult, if not impossible, to obtain. The best flint-glass is liable to such defects as *striæ* or *wreath*, *knots*, *threads*, and *tears*. The striæ consist of undulatory appearances, resulting from a want of uniform density in the glass, so that the rays of light, in passing through it, are refracted and dispersed in different directions, thus producing a wavy effect, not always, indeed, apparent to the eye, but painfully evident when such glass is applied to the construction of an optical instrument. Flint-glass is more subject to this defect than any other kind. Knots are opaque particles of earthy matter from the furnace, or abraded from the glass-pot; or they may consist of particles of glass-gall, or imperfectly vitrified grains of sand. Threads and tears consist of partially vitrified clay from the roof or glass-pot, not uniformly mixed with the glass, and being different in colour, and in their expansion and contraction by heat, dispose the glass to fly to pieces without any apparent cause. The want of clearness arising from minute bubbles (*seed*) diffused through the glass, in consequence of its not having been kept in a sufficiently fluid state, has been already adverted to. All these defects, with the important exception of striæ, can with care and attention be got rid of in the manufacture of *crown* glass, and in this case, where the materials do not differ greatly in specific gravity, striæ are of less importance. In flint-glass, however, where the materials vary so much in density, it is difficult to obtain a disc of homogeneous glass a few inches in diameter, such as is required for a lens, the correct action of which depends more on the equal density or refractive power of the glass than on whiteness or brilliancy. If the raw materials be not well incorporated, a pot of glass is apt to have an excess of oxide of lead in some parts, and a deficiency in others, leading, of course, to different densities in different parts of the mass. In slowly cooling a pot of uniform glass, the heavier silicate of lead always subsides, while the lighter alkaline silicate is found in excess above. If, to prevent this separation of the two silicates, the pot be rapidly cooled, the glass becomes too brittle. Want of uniformity in the glass arises from the unequal heating of the pot in the furnace, in which the sides are more heated than the bottom. It has been proposed so to construct the furnace as to allow of heat being applied below the pot, in order to expand and diffuse the denser glass. Agitation is supposed to be favourable to the production of a uniform glass; and it has been proposed to ladle the glass from one pot to another, or to stir it up with a rod of iron, cased in stoneware, to prevent the naked iron from colouring the glass. After agitation, the pot is to be left quiet for a short time, for the air-bubbles to disperse, and, when the glass is *fine*, it is to be cooled

quickly, or gathered out on the end of a rod. If the pot be cooled, the mass is broken up by a hammer into conchoidal lumps, to which a lenticular shape is given by raising them to a dull red heat in a reverberatory furnace. The mass may also be cleaved while cooling, so that the fracture may follow the direction of the faulty parts. It is said that masses of homogeneous glass of 40 lbs. weight have thus been obtained.

For many years, English flint-glass, with about 10 per cent. increase of lead, and of the sp. gr. 3·25 to 3·35, technically called *heavy glass*, was used for telescopes at home and abroad. It was worked in the following manner, as described by Mr. Pellatt:—A ladle in the form of a sugarloaf, about 5 inches in diameter and 7 inches deep, is dipped carefully into the metal, which has been previously skimmed: when filled, it is taken out of the pot, and suffered to get partially cool: to the large end of the sugarloaf-shaped piece of glass thus produced, a glass-blowing iron with a hollow disc is welded, and placed to the opening or mouth of the pot for re-heating. When sufficiently soft, it is blown into a muff or cylinder: the end furthest from the blowing-iron is cut off; the cylinder is flattened into pieces or plates of 14 inches in length and 10 inches in width, and about half an inch in thickness, and annealed: after which the plates are sold to the optician, for cutting and grinding into discs.

Many years ago, M. Guinand,[1] a clockmaker, of Brenets, near Neufchatel, in Switzerland, succeeded in producing flint-glass exempt from striæ, by some method of rabbling or stirring up the liquid glass before cooling. In consequence of this, which may be regarded as the first successful experiment in the production of optical glass, Guinand was invited to Bavaria, where, in conjunction with Frauenhofer, he made a number of object-glasses, the largest of which, 9 inches in diameter, was used in the telescope at the observatory of Dorpat. After his return to Switzerland, Guinand sent some small discs of his flint-glass to the Astronomical Society of London, and, some time after, a disc of 6 inches in diameter, which at that time was considered a rarity. A committee, composed of Messrs. Dolland, Herschel, and Pearson, reported favourably thereon; but Guinand's negotiations with the Society did not lead to any decisive measures, and his proposals to the French government were equally fruitless. The Astronomical Society of London appointed a committee, consisting of Messrs. Herschel, Faraday, Dolland, and Roget, for the purpose of making experiments on the manufacture of optical flint-glass. Dr. Faraday conducted the experiments, and Mr. Pellatt liberally placed at the service of the commission the resources of his glass-house, and his own large experience. The result of this inquiry was the production of a glass of remarkable purity, consisting of a combination of silicate of lead with borate of lead: the materials were perfectly pure, and vitrified in a platinum crucible. If the air-bubbles are slowly disengaged, a little spongy platinum is thrown in, in fine powder, and the glass stirred with a platinum spatula. The powder subsides, and the glass may be poured off quite clear and free from striæ. This highly refractive and dense glass has been of assistance to Dr. Faraday in his physical researches, but has not answered the purpose for which it was originally intended, on account of its gradual decay.

Optical glass continued to be made in Bavaria according to Guinand's method, but its production was confined to a working optician, M. Mertz. Guinand, shortly before his death, also revealed his secret to his wife and his two sons.[2] One of the latter sold the secret to M. Bontemps; but, on attempting to apply it, it failed;[3] whereupon, the contract was broken. But M. Bontemps, considering with great fairness that the principle of the method had been disclosed, and only required study and experiment to carry it out, associated himself with the younger Guinand, and at length, in 1828, succeeded in producing good optical glass, one disc measuring 12 inches, another 14 inches, and a number of others of smaller dimensions. After this, the Guinands continued for some years to manufacture optical glass on their own account: they disposed of the secret to M. Daguet, of Soleure, who sent to the Great Exhibition discs of flint-glass varying from 4 to 15 inches in diameter, and of crown-glass, from 4 to 6 inches. When subjected to the severe test of polarized light, some discs of crown glass were found to be not quite uniform in density. The higher temperature required for the fusion of crown-glass is one reason why it is so difficult to make discs of large size in this glass.

(1) An interesting memoir of this remarkable man was read before the Society of Physics, &c. of Geneva, 19th February, 1823, and is translated in the Quarterly Journal of Science, vol. xix., published in 1825.

(2) Guinand died in 1823. In 1816 he produced several telescopes of large size and remarkable excellence. They are described as "the work of an old man of upwards of seventy, who himself manufactures the flint and crown-glass which he uses in their construction, after having made with his own hands the vitrifying furnace and crucibles; who, without any mathematical knowledge, devises a graphic method of ascertaining the proportions of the curves that must be given to the lenses; afterwards works and polishes them by means peculiar to himself; and lastly, constructs all the parts of the different mountings, either with joints or on stands, melts and turns the plates, solders the tubes, prepares the wood, and compounds the varnish."

(3) According to Mr. Pellatt, the following was the process adopted:—

"A long hollow cylinder or sheath of fire-clay, closed at one end, with a bore sufficiently large to admit of a strong blowing-iron, was brought to a red heat, and introduced into a pot of melted glass. This agitating-iron had a long handle, with a flat ring, or hand-guard, which rested while in use upon the shoulders of the pot: it was then introduced into the fire-clay cylinder or sheath, and when the metal was at its utmost intensity of fusion, the mixing began, and continued for many hours, until the operator presumed the striæ were dissipated: then, by gradually reducing the heat of the furnace, the glass became too stiff for agitation, and the pot and its contents were annealed in the furnace. Crown-glass will not allow of so many hours' intense fusion and agitation as flint-glass, owing to its liability to devitrify. M. Bontemps does not assert that he always succeeded in the stirring system for flint-glass. He sometimes found hard masses of small cords, as it were, felted together: these he thought were caused by the chemical action of the glass upon the fire-clay cylinder and pot; but they spread in the operation of cooling. . . . He recommended that an entire pot of flint metal, fused upon the agitation system, should be emptied upon an iron table, and cast the same as plate-glass."

If we attempt to lower the point of fusion by varying the composition, the glass then becomes so attractive of moisture as to be worthless as an object-glass. If, on the other hand, we attempt to make a very *dry* glass, there is a liability to crystallization and devitrification in the cooling.

M. Bontemps[1] is said to have overcome the difficulties of the manufacture of optical glass: he exhibited last year discs of flint-glass 29 inches in diameter, and of crown-glass of 20 inches, and others of smaller size, which are said to pass satisfactorily through the ordeal of polarized light, thus showing them to be of the same density throughout. The 29-inch disc, however, presented a few striæ near the surface, which, it was thought, would be ground out in giving the lens its curvature. These glasses were from the works of Messrs. Chance, who have engaged M. Bontemps to superintend this department of their large and varied establishment.

After this long detail, the reader will probably expect us to describe the process of making optical glass. We regret to say that we are unable to do so: it is still a secret confined to the few whose labours suffice to supply the demand for large lenses. The circumstance of a very limited demand is a good reason why the possessors of the secret have been able to retain it so long. If optical glass were required in the large quantities in which other descriptions of glass are manufactured, there cannot be a doubt that its production would soon become one of the common operations of the glass-house.

Mr. James Nasmyth has recently proposed a method of making optical glass, which not only promises well, but may be *the secret* of his predecessors. Supposing the materials to be pure and in due proportions, and that the vitrification is perfect, he reasonably supposes that the variations in density arise from removing the glass from the melting-pot while in the fluid state. He therefore proposes to place a large pot of the most perfectly composed glass in the furnace, and to subject it to the highest degree of heat which it can stand, in order that, by rendering its contents as completely fluid as possible, the particles may arrange themselves in strata of perfect homogeneity and uniformity of density. In order to ensure this result, this high temperature is to be kept up for at least three days. A slight variation in density will be found in the top stratum of glass, as compared with that at the bottom of the pot; but the variation of the successive parallel strata would be so gradual, that one would not vary from another in any appreciable degree. The pot is then to be left perfectly quiet, and the furnace allowed to die out gradually, taking care that no draught have access to it, or any irregularity take place in the decrease of temperature. The cooling may thus require about twenty days. When the pot is cold, the glass is to be removed, and cut into slices parallel to its top surface, by the simple means employed by marble-cutters. The result would probably be a series of discs of absolutely perfect glass. Mr. Nasmyth has tried this method on a considerable scale with crown-glass with perfect success; masses of the most splendid glass having been obtained, to all appearance perfectly free from striæ or other irregularity.[2]

This ingenious method is evidently inapplicable to flint-glass: the long-continued application of heat would dissipate its alkali, and the long repose would cause the lead to subside, so that no two horizontal layers, however thin, would possess the same density. Mr. Simms, the eminent optical instrument maker, states, that in only two instances has he succeeded in making unexceptionable object-glasses of English flint-glass, and these had only 3½ inches aperture. The flint-glass as hitherto obtained from the Continent, in discs of from 4 to 9½ inches diameter, is very costly; and the risk of its not turning out well after the labour of grinding has been bestowed upon it, has deterred the instrument-makers generally from making so costly an experiment. It is therefore to be hoped that Messrs. Chance will be encouraged in their undertaking, so important to the interests of science; and it is interesting to learn from Mr. Simms that, so far as he has tried it, their optical flint-glass is equal to the very best that was prepared by the elder Guinand.

Section VI.—Crown-Glass.

The glass commonly used for window-panes is a silicate of soda and lime: it is more difficult of fusion, and less easily worked, and much harder than flint-glass, and hence does not well admit of being shaped into vessels, or ornamented by cutting and grinding. Crown-glass is manufactured in the form of flat discs or *tables*, 52 inches in diameter. At the Great Exhibition, Messrs. Chance displayed some tables 66 inches in diameter.

The arrangement of the crown-glass furnace is similar to that of the flint: it is arranged in the centre of the cone, and contains from four to six pots, each of the capacity of half a ton. These pots are open at the top, not hooded as in the flint-glass pots. There are several subsidiary furnaces adjoining or round the inside of the cone; also an annealing furnace, or *arch*, and an oven for annealing the glass-pots before they are set. The *fritting* furnace, called *colcar*, from the French *calquaise*, is reverberatory in its action, and is used for calcining or *fritting* the materials before they are placed in the glass-pots for vitrification; the object being to effect a partial union between the silicic acid and the alkaline bases, so that the latter may not be volatilized in the furnace; this alkaline vapour not only being a positive loss, but acting injuriously on the pots and sides of the furnace. The other furnaces are used for softening the glass while passing through the successive stages from a globe into a flat table:—the *blowing furnace*, used to facilitate the blowing of the glass into a large globe, the *bottoming hole*, the *nose hole*, and the *flashing furnace*,—the use of which will be explained presently.

The materials consist of fine sand, chalk, soda-ash or crude carbonate of soda, or salt-cake, which is dry

(1) This gentleman has just published an interesting "Examen des Verres, Vitraux, Cristaux, composant la Classe XXIV. de l'Exposition Universelle de 1851."

(2) Memoirs of the Royal Astronomical Society, vol. xvi. 1847.

sulphate of soda; also a little charcoal, black oxide of manganese, arsenious acid, and occasionally a little oxide of cobalt, to correct any defects in colour arising from the presence of oxide of iron. As the soda is liable to considerable fluctuations in its value, no fixed proportions of materials can be agreed upon, and the manufacturer has to determine the amount of real alkali in every fresh supply of ash. When all the alkali is soda-ash, the usual proportions are, 100 parts quartz sand, 35 to 40 chalk, a quantity of soda-ash containing about 8 parts soda, and from 150 to 200 old broken glass, or cullet. The proportion of arsenious acid and manganese can only be ascertained by trial. If the materials are to be calcined, they are put into the colcar, and well stirred with iron paddles and rakes, to expel water and burn off carbonaceous matters, as also to drive off carbonic acid from the chalk, and to unite the base of the alkaline carbonate with silicic acid, displacing the carbonic acid, and thus prevent the alkali from being volatilized in the glass-pot. The temperature of the colcar is gradually raised during three hours, and when the mixture becomes pasty it is diligently stirred, to facilitate the extrication of carbonic acid and the combustion of carbonaceous matters. Towards the end of the third hour, the temperature is considerably raised, and at the expiration of the fourth, while the mass is hot and soft, it is raked out into large cast-iron trays, and cut by a spade into square cakes, which are piled away for use. These *frit-bricks* are supposed to improve by age, and are sometimes kept for twelve months or more. Where the fritting is omitted, as it now often is, the materials must be thoroughly dried before the founding; for which purpose the sand is first calcined at a dull red heat in the colcar, then carefully sifted: the chalk is also raised to a more moderate heat, for the purpose of expelling moisture, not carbonic acid. The sand and chalk are finely sifted and thoroughly intermixed with the other materials, also in a dry and pulverulent form. The mixture is shovelled into the pots when they are at a white heat. The furnace being at its greatest heat, the first quantity thrown in fuses down in about 8 hours; another portion is then thrown in, and so on until the pot is sufficiently full. Vitrification is usually complete in about 18 hours. When gas ceases to be disengaged, the temperature is gradually lowered, by closing the draught-holes, and the chinks in the doors of the cave are stopped with mortar. In a few hours the glass is perfectly clear: the fire is then raised a little, and the glass-gall being skimmed off, the glass is ready for working. In order to preserve a clean surface, an earthenware ring of the same material as the pots, and about 2 feet in diameter and 3 inches thick, is floated on the melted glass after the surface is skimmed. The surface of the glass is much cleaner within the ring than without.

It is difficult to convey a complete idea in writing of the remarkable series of processes by which a lump of glass is expanded into a large sheet or table. In the Great Exhibition Messrs. Hartley & Co., the eminent crown-glass manufacturers of Sunderland, had a most instructive series of specimens, showing, first, the lump of glass adhering to the blowing tube; then the various shapes which it is made to assume, until it finally becomes a large table. Those persons who studied these specimens, as well as the huge glass-pot (represented in Fig. 1069) and the model of the crown-

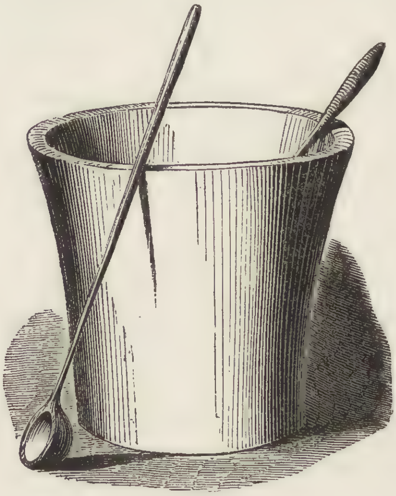


Fig. 1069. CROWN-GLASS POT.

glass furnace, will be the better qualified to follow our description. Indeed, the general intelligence of the public would be promoted, writers on the useful arts assisted, and the cause of education forwarded, if an industrial museum, such as the Great Exhibition, could be made permanent, although on a much smaller scale; nor do we see any good reason why every town should not have its Useful Arts Museum, open to all, with competent persons to give instruction therein. Had such powerful educational means been in existence during the last half-century, many a poor inventor would have been spared much useless toil, anxiety, and expense.

The man collects on the end of his blowing-tube, from the inside of the ring, as much glass in successive layers as will form a disc or table of about 9 lbs. weight. An experienced workman seldom fails more than an ounce or two in the correct weight. After cooling the blowing-tube which has been heated in the melting furnace, by letting water drop upon it, he rolls this mass of glass, technically called the *piece*, upon the marver, into a pear-shaped lump, *a*, Fig. 1070, while a boy slightly distends it by blowing. It is next held in the mouth of the small blowing-furnace to soften: again rolled on the marver to correct inequalities in the thickness of the sides, and to collect the great mass of glass at the lowest point, thereby elongating the neck, as at *b*. In this marvering the outer extremity of the glass is made conical, and the extreme end is called the *bullion*. In again blowing out the bulb, the man supports it on a horizontal smooth iron rod, called the *bullion-bar*, placed across a stool, or across a pit in front of the marver, and he expands the bulb until it is nearly spherical, as at *c*: to preserve the perfect form of the sphere, the man,

while blowing, gives it a continuous motion along the bullion-bar, but the effect of this is to form waved lines round the centre of the table. At Mr.

Fig. 1070. PROGRESS OF THE MANUFACTURE OF A TABLE OF CROWN-GLASS.

Hartley's works the bullion-bar is dispensed with; the glass is supported by a tube attached to the bullion, and held by a boy while the blower causes the tube to revolve. The boy is protected from the great mass of hot glass by a shield through which the supporting rod passes. The globe is next softened at the blowing-furnace and blown out until quite spherical. It is then conveyed to the bottoming-hole, Fig. 1071, which is similar to the flashing-furnace, but has a smaller opening: here it is exposed to the direct action of the flame, the man being screened from the heat by a wall in front and a little on one side of the furnace. The tube is supported on a hook projecting from the wall, and in revolving the globe the part opposite the tube becomes softened by the heat, and yielding to the action of centrifugal force, assumes the fo m shown at *d*, Fig. 1070. It is then removed, and another man applies a pontil tipped with melted glass to the centre of the flattened part, when the first man detaches the blowing-pipe by touching the neck of the globe with an iron wetted with cold water. The blowing-pipe carries with it a piece of glass, leaving a corresponding hole in the flattened sphere at a point exactly opposite the attachment of the pontil, as shown at *e*, Fig. 1070. By the action of heat and centrifugal force, the flattened sphere becomes more and more flat, while the hole becomes larger and larger, and at length entirely disappears on the glass flying out into a flat table. This final result is approached by gradual steps. The glass is held by the pontil and exposed to a

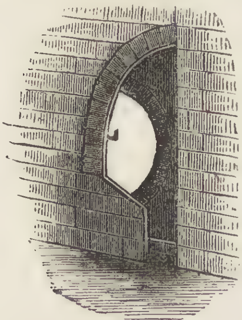


Fig. 1071.
THE BOTTOMING-HOLE.

moderate flame before the nose hole: it is rotated with gradually increasing velocity, when the hole caused by the removal of the blowing-pipe enlarges. It is next heated more intensely before the flashing-furnace, and acquires the form shown in Fig. 1072

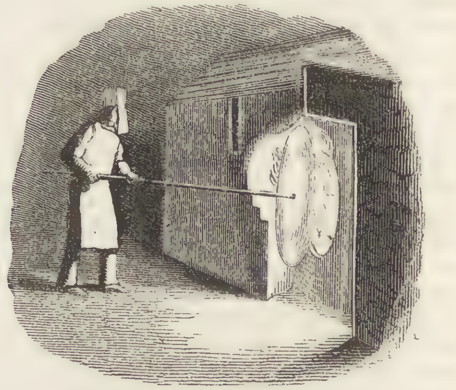


Fig. 1072. THE FLASHING-FURNACE.

By increasing the velocity of rotation, the flattened globe at length flies completely open with a noise something like that produced by quickly opening a wet umbrella: in this way a flat circular disc nearly 60 inches in diameter is produced, of uniform thickness except at the point of attachment to the pontil, where there is a swelling called the *bull's-eye.*[1] A sheet of such dimensions would fold together while in its soft state if the man were to cease to rotate it; he therefore continues the motion until the table is sufficiently cool. It is then placed on a large iron fork, held by an assistant; the pontil is cracked off, and the plate transferred to the annealing arch Fig. 1073, where it is made to rest on edge in two strong parallel iron supports, running the whole length of the annealing kiln. The arch is of sufficient capacity to receive two rows of tables, as shown by the dotted circles: the annealing is continued for 24 hours, during which the whole arch is raised to a uniform heat, and allowed to cool gradually. A shorter time suffices when the arch is strongly heated at one end, and nearly cold at the other, while the tables are slowly moved forward towards the cold end.

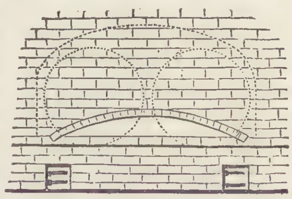


Fig. 1073.

A pot containing half a ton of metal will produce 100 tables. At an ordinary crown-glass house 4 such pots are emptied in three days every week. The glass-gall, and the residue in the pots, are *refined* by being

(1) The glass at the edge of the disc is also in some cases a little thickened. It is evident that the portion of the glass attached to the end of the blowing-tube afterwards becomes the edge or outer rim of the table: the thickening of this edge is prevented by a *cutter*, attached to the marver, consisting of an iron crescent, into the concave of which the man places the neck of the piece or solid ball of glass, while the boy is distending it by blowing: it is thus prevented from thickening at that point. In subsequently reheating and blowing, another form of cutter is used. The edge of a bar of wood attached to the marver will even answer the purpose.

poured into cold water. The glass is thereby disintegrated, and, falling into a coarse powder, a portion of the saline impurities is dissolved out: the glass on being drained dry is mixed with fresh raw materials.

Section VII.—Cylinder-Glass.

On the continent of Europe the above method of making window-glass is not adopted, but instead of it the glass is first formed into a cylinder, closed and rounded at both ends, which are then cut off, and a crack being run down the length, or the cylinder itself attached to a three-pronged pontil, is cut open with shears, as in Fig. 1074. The cylinder is then flatted out in a furnace.[1] The glass for the Great Exhibition was made somewhat in this way. It is coarser in texture, more wavy and dull than crown-glass, but it allows of larger sheets being manufactured; for crown-glass cannot be cut up without considerable waste, in consequence of the circular form and the central bull's-eye. But while the glass manufacture was subject to the regulations of the Excise, it was more profitable for the maker to produce crown-glass tables than cylinder sheets, because the duty was levied on the weight of glass produced, and not on the number of sheets, and it is possible to produce a greater yield from the same weight of crown than of cylinder-glass, in consequence of the smaller thickness of the former, and also not having to cut off any portions, as is the case in the manufacture of the latter.

Fig. 1074.

The manufacture of cylinder-glass is of German origin; whence the product is sometimes termed *German plate-glass;* and on the introduction of the process into England it was called *British sheet-glass.* It is also known as *broad window-glass, spread window-glass,* and *inferior window-glass.* This last term arose from the coarseness of the materials used, the alkali being soap-boilers' waste and kelp; but of late years the manufacture has been considerably improved, and it is now inferior to crown-glass in lustre only.

Broad-glass is made without flashing. The raw materials are fritted with considerable agitation for 20 or 30 hours, and the frit is introduced into the glass-pots red-hot from the colcar. It is vitrified and ready for use in 16 or 20 hours The workman then collects a massive glass ball round the knob of his blowing-pipe, which is pushed forward until a groove is produced at *a*, Fig. 1075. He then rounds the ball on the marver, and slightly distends it by blowing until its form becomes that shown in section, Fig. 1075; and from the thick mass of glass below the air-bubble, the cylinder is distended and lengthened, the glass being first made to assume the width, and then the length of the intended cylinder. The ball of glass having been heated, the man then holds it up, in a vertical position, over his head, and blows into it: the soft glass yields to the distending power, while the heavy bottom, descending by its own weight, forms a sort of flattened bottle, Fig. 1076. The proper width of the intended cylinder being thus attained, the pipe is quickly lowered so as to have the glass below instead of above, and the man keeps swinging it backwards and forwards, blowing into it all the time. The thick bottom retaining its heat much longer than the thin sides, yields to these two forces and increases in length, until it settles by cooling into a form similar to that of Fig. 1078. If the man were to blow without swinging, the bottle would assume the form indicated by the dotted line.

Fig. 1075.

Fig. 1076.

Fig. 1077. BLOWING AND SWINGING CYLINDER-GLASS.

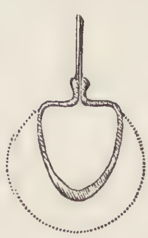


Fig. 1078.

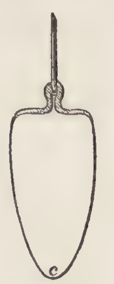


Fig. 1079.

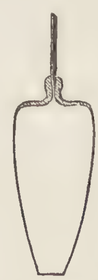


Fig. 1080.

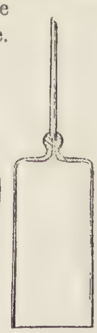
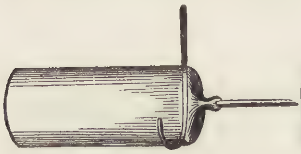


Fig 1081.

In this way, by repeated heating, swinging, and blowing, the intended length of the cylinder is obtained, and the glass is of the form shown in Fig. 1079: it is conical, and terminated by a hemisphere, of which the middle point *c* is the thinnest part of the whole vessel. The man now blows air into this vessel, and before removing his mouth, closes the aperture of the pipe with his thumb: he then holds the end *c*, Fig. 1079, in the flame until it bursts under the increasing elasticity of the enclosed air. The thick and uneven margin of the aperture is trimmed with scissors, and

(1) Although this method of making sheet-glass is not so well known as that described in the preceding section, it is at least as ancient. In the *Diversarum Artium Schedula,* which has been referred to the 13th century, a complete description is given of the mode of manufacturing cylinder-glass.

enlarged with the pucellas to the proper diameter, as in Fig. 1080. The other parts are also straightened, and brought to a uniform diameter, as in Fig. 1081. In long and wide cylinders, the lower part is apt to become too thin, and requires extra glass to be incorporated with it before the cylinder is opened. The neck or cap is then removed, by supporting the cylinder on a wooden rod and turning the upper part two or three times in the curve of a bent iron heated to redness, as shown in Fig.



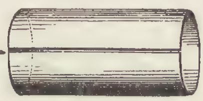


Fig. 1082. *Fig.* 1083.

1082: a drop of water allowed to fall on the heated line produces fracture and separation of the cap. By a similar process a crack is made down the length of the cylinder, and it is now in the form shown in Fig. 1083, ready for the operation of spreading or *flatting* into a sheet of glass. This is performed in a furnace, the principal parts of which are shown in perspective, Fig. 1084 In the arched space A, *a* is

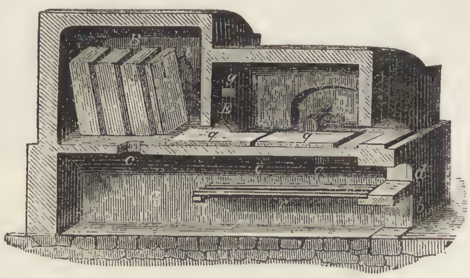


Fig. 1084. FLATTING-FURNACE.

the ash-pit and *r* the grate; *b* the ash-pit door, and *d* the stoke-hole. The flame enters the upper part of the furnace through the openings *c c*, first plays on C, which is called the *flatting-hearth*, then passes into B, the annealing or cooling-furnace, and escapes by the flue or channel D, by which the cylinders are introduced. C and B are connected by means of a low-arched wide aperture, E, to allow the passage of the plates, and also by a smaller higher opening *g* for the admission of flame. The heat is regulated by opening or closing the apertures *c c*. The flattener stands in front of the aperture *l;* the man at the cooling-furnace before *m*, and an assistant pushes the cylinders forward along a railway into D. The *spreading-plate* or *flatting-stone* must be perfectly even, free from roughnesses or inequalities, as the soft glass of course moulds itself to the surface upon which it is flattened by heat. This plate is made of fire-proof clay mixed with cement, and ground smooth; or it is made of a thick plate of devitrified glass: in this country, the sandstone of Godstone in Surrey has been found to answer the purpose. The fact is, however, that the choice of a proper flatting-stone constitutes one of the chief difficulties of this elegant and remarkable branch of the glass-manufacture.

The operation of spreading is begun by introducing the cylinders into the long flue leading into D, and as they are pushed forward they gradually soften. A man standing before the aperture *l* takes up one of the cylinders with an iron tool, bent at a right angle, and places it on the flatting-stone with the cracked side uppermost: the cylinder soon opens, and he makes it straight and even with a rod of iron furnished with a wooden polisher, Fig. 1085, dipped in water

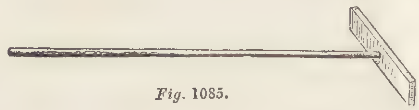


Fig. 1085.

before being used. All the curves and lumps being thus removed, the sheet is pushed into the annealing oven, where it cools down. Another man then places it on edge in an inclined position, and when 30 or 40 sheets are thus collected, an iron rod *s*, Fig. 1084, is inserted; and the processes are conducted in this way until the annealing-furnace is filled.

Such is the German method, which has long been practised on the Continent. In 1842, Messrs. Chance of Birmingham introduced it into England, with certain improvements, which they patented. Instead of at once removing the glass from the flatting to the annealing-furnace, and lifting it to the cooling-bed while soft and liable to distortion, they flat and cool it by passing it through a succession of decreasing temperatures, so that it is not lifted until it becomes quite stiff and rigid. By this arrangement the workman can flatten while the annealing is going on, which could not be done in the old process, because the temperature of the flatting kiln must be reduced with that of the annealing kiln to which it is contiguous, thus leading to the successive heating and cooling of the kiln, and waste both of time and fuel. At Messrs. Chance's establishment the flatting and annealing kilns are two circular buildings communicating with each other, each consisting of an exterior wall A, Fig. 1086, and interior masonry work B, the intervening space being a circular arched vault. In each vault is a cast-iron frame F, moving on casters, and capable of being turned round by a winch on the outside. The frame in the flatting-kiln carries the flatting-stones and *lagres* L, 8 in number, and in the annealing-kiln a number of metallic wires D, radiating towards the centre of the building, for supporting the sheets of glass. The flattening-kiln is heated by the grate G, and in order that the stones and lagres, which will have cooled during the rotation, may be re-heated and arrive at the position E at a proper temperature, a second smaller grate is placed at H. If coke be used, a chimney at C will be required, but with wood fuel it will not be needed. Partitions P are placed at certain intervals, to prevent the too rapid dissipation of the heat from those parts where it is most required, and to retard the entrance of cold air through the openings in the external wall. At the bottom of the partitions are spaces to allow the frame with the stones and glass or the wires and glass to pass below. The space I is reserved for re-heating the wires. The

space J, on which the glass is shifted from the lagres to the wires, is lighted by gas. The kiln is worked in the following manner:—The cylinder of glass is first placed in the position K; then in that of L; thirdly it is introduced through the external wall and placed on a stone M, suspended over the lagres: it is lastly placed in the position N on the lagre beneath. To prevent the cylinder rolling off, the stones have a ledge *l*. This part of the kiln, 3——3, Fig. 1086, is shown separately in Fig. 1087.

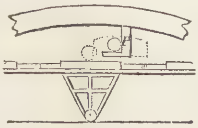


Fig. 1087.

The frame F is then turned round till the cylinder of glass occupies the position O opposite the working hole *o*, through which it is then flattened in the ordinary way. From O the glass passes to G, and thence successively to R; thence it is shifted to the position T on the wires, by the flattener using his instrument through the opening S; and after passing through the successive positions arrives finally at V, where it is drawn at W fully annealed. Thus each sheet of glass after having been flattened remains on the stone during the time that other cylinders are being flattened, and before the sheet is lifted off the stone, it has passed through a gradually decreasing temperature, and has become rigid. The annealing also is carried on without lowering the temperature of the kilns by the movement of the frame, and the sheets being isolated by the wires, become more quickly annealed.

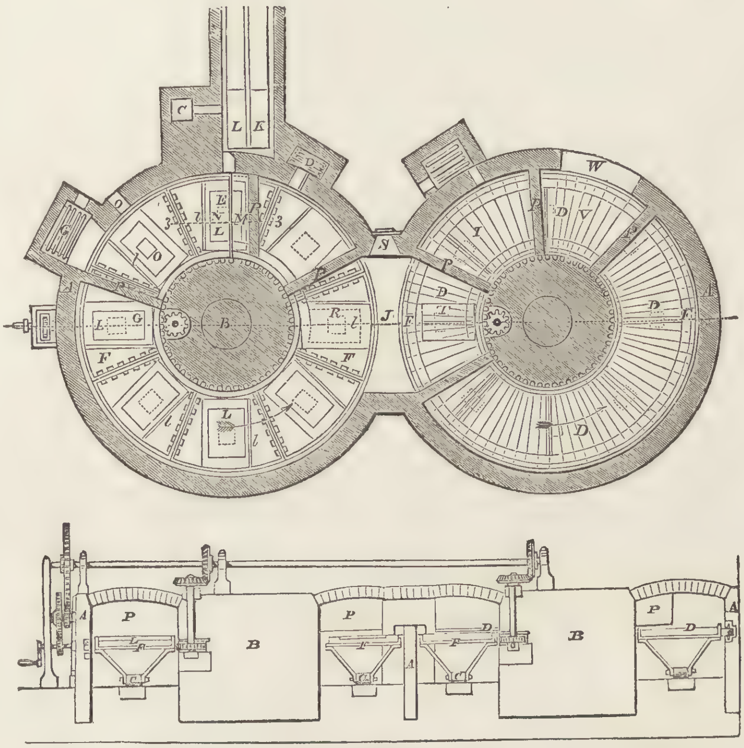


Fig. 1086. PLAN AND ELEVATION (IN SECTION) OF MESSRS. CHANCE'S FLATTING AND ANNEALING KILNS.

Mr. Hartley of Sunderland exhibited an admirable series of illustrations of this branch of the art at the Great Exhibition. This gentleman is also an improver on the German method. In his process the operation of flatting does not occupy more than a minute; the flatting-stone is made to revolve in such a way that the cylinder upon it is gradually exposed on all sides to the action of the fire, and thus one side of the cylinder is not hotter than the other. It is difficult to obtain perfectly flat glass for polishing, on account of the film of air between the flatting-stone and the cylinder. Mr. Hartley overcame this difficulty by perforating the flattening-stone with holes $\frac{1}{8}$ inch in diameter, and about 1 inch apart.

One of the most recent improvements is Mr. Farthing's arrangement, by which the kiln is heated by flues under the floor, around the walls, and over the arch, thus protecting the glass from dust or hard particles from the fuel, and allowing of the consumption of fuel of the cheapest kinds.

Section VIII.—Plate-Glass.

This beautiful variety of glass is similar to crown-glass, the only essential bases with silicic acid being soda and lime; but a larger proportion of alkali being used, the point of fusion is lower than in crown-glass. Plate-glass requires to be as transparent and colourless as possible, in order that, when used for mirrors, the light may be reflected from the amalgam at the back; these qualities can only be ensured by purity in the materials. A good mirror should also reflect an image in its true and natural form, without distortion of any kind; hence there must be no waves or lumps in the glass to produce irregularity of reflection. The difficulties of producing faultless plate-glass are almost as great as in the case of optical-glass; and as the working arrangements are of a very costly description, the manufacture is in this country in the hands of a few powerful companies. It cannot, however, be said that they have attained perfection in the art. At the Great Exhibition, plates of enormous dimensions were exhibited, but in quality they were not equal to the French. A writer in Newton's *London Journal*, Vol. XXXIX, offers an ingenious explanation of the cause

of our inferiority in this respect, by referring to the fact, that many neutral salts combine together by fusion in atomic proportions, and form new and definite compounds: thus, carbonate of potash and carbonate of soda, when mixed atom for atom, unite, and produce a compound more easy of fusion than the more fusible of the two; so also fluor spar and sulphate of lime, two remarkably infusible substances, melt readily, when mixed at a low red heat, into a mobile transparent fluid: so also with respect to the silicates: a mixture of silicate of potash and silicate of soda will, if in atomic ratios, fuse much more readily than either of them alone; but if one of them be in excess, (the silicate of soda, for example,) then the silicate of potash would unite with exactly sufficient of the silicate of soda to produce a glass of comparatively easy fusibility; while the less easily fusible silicate of soda in excess, would form a kind of network throughout the mass. This less fusible glass thus entangled in the more fusible, and of different density therefrom, would form striæ, and produce unequal refraction and distortion of figure. The excellence of the plate-glass of St. Gobain is said to be due to the fact that it is a true chemical compound, consisting of one atom of the trisilicate of soda and one atom of the trisilicate of lime, with a small percentage of alumina. The English plate-glass, on the contrary, consists of a mixture of two glasses of different densities. On placing a specimen of French and English plate side by side, and viewing some distant object in each by reflection, the French glass will give a clear, sharp outline, while the English will reflect two or more images in a hazy and imperfect manner. It must, however, be remembered that the French are particularly careful to ensure the purity of their materials, that they manufacture the most costly description of plate-glass, and that the specimens at the Great Exhibition were *picked* from a very large stock. Our manufacturers, on the contrary, work for the million, a very large portion of their supply being for glazing shop-windows and the windows of private houses, as well as for cheap looking-glasses; whereas, the French never glaze with plate-glass, and their choicest productions being costly, the demand for them is limited. It is of far more importance that the masses of the people should be supplied with such an article of comfort and luxury as plate-glass, even though it be of a somewhat inferior description, than that the manufacture of the superior article should be so costly as to place it within the reach of the wealthy only. The French plate-glass is unquestionably good; but it is doubtful whether it could be applied to the purposes of glazing, as it would be likely to suffer from the action of the weather. The Editor has been informed by a plate-glass manufacturer, that if the materials be combined in the melting-pot in true atomic proportions, the portion of the alkali volatilized by the heat will disturb the atomic arrangement; and that if an excess of alkali be added to compensate for this loss, then the glass becomes *basic* or alkaline, and, attracting moisture from the atmosphere, soon loses its polish and decays. In plate electrical-machines, a dry glass is of importance; and hence crown-glass, although inferior in colour, is to be preferred. We trust, however, that the effect of the Great Exhibition will be to give a healthy stimulus to our plate-glass manufacturers; and they will certainly be moving in the right direction if they follow the example of the St. Gobain Company, and engage the services of a Gay Lussac as consulting chemist.

In this country the best quality of soda ash is employed. At St. Gobain pure carbonate of soda is obtained by decomposing sulphate of soda with lime and charcoal. Potash is not used for plate-glass, except a small portion of nitre to destroy carbonaceous matters. Glass made with soda and lime flows more freely than that made with potash and lime at the same temperature, and is hence better suited for casting. The glass-gall of the soda glass, consisting of sulphate of soda and chloride of sodium, is also more volatile than potash gall, and is hence more readily got rid of from the open pots in which the glass is fused. The lime may be introduced in the form of chalk, quicklime, or dry slaked lime. The sand and alkali must be well purified from oxide of iron, and all the materials, with the exception of the cullet or broken plate, must be in powder, sifted and ground if necessary. In England, arsenic is used, and in France, borax: the latter material greatly improves the colour, but is said to produce a soft glass.

In the manufacture of plate-glass, the materials are not fritted, as was formerly the case, but are sufficiently pure to be placed in the pot in 3 successive charges: they are melted in open pots, and by the side of them are other crucibles or *cisterns*, Fig. 1088, called *cuvettes*, in France, where they are quadrangular in form, into which the glass is ladled when ready for casting.

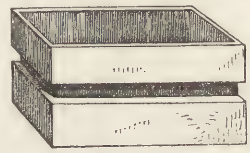


Fig. 1088.

The English pots and cisterns are of the same form as those used in the manufacture of crown-glass. At the Thames Plate-glass Works, the melting-pots are 50 inches deep, and 48 inches across at the brim, and are capable of holding from 28 to 30 cwt. of glass. The cisterns hold from 3 to 6 cwt., and have an indented ring about one-third of the way up from the bottom, into which the limbs of the huge tongs fit, at the casting. Vitrification is complete in about 20 hours, and when properly refined, a copper ladle, 10 or 12 inches in diameter, fixed to an iron handle 7 feet long, is plunged into the glass-pot, and raised full of melted glass; the ladle being supported by an iron rest held by two men, its contents are conveyed to another furnace, and poured into the cistern, which is filled in this way and left for 12 hours to fine, samples being withdrawn from time to time for examination. During the first 6 hours the founding goes on, and in the second, the fining; during which the temperature is lowered to the proper point for casting.

The casting is performed on massive tables of

metal, which at the Thames Plate-glass Works are of iron, 20 feet long, 11 broad, and 7 inches thick, made perfectly smooth and level. Brass or bronze was formerly used; the bronze slab at St. Gobain weighs 50,000lbs., and cost 4,000*l*. But the liability of this metal to crack first led the British Plate Company to make trial of iron, which was found to be quite successful; and at St. Gobain they have abandoned the use of bronze for the more common metal. The foundry at Ravenhead is described as a fine room 339 feet long, 155 feet wide, and lofty in proportion. The melting furnaces, which are ranged down the centre, occupy about one-third of the whole area of this apartment. The annealing ovens A F, Fig. 1089, are placed in two rows, one on each side of the foundry, and occupy the greatest proportion of the side walls. Each oven is 16 feet wide and 40 feet deep. Their floors being level with the surface of the casting table T, the plates are deposited in them as soon as they are cast.

When the melted glass in the cistern is in the proper state for flowing readily and equably, the cistern is taken out of the furnace by means of tongs fitting in the groove, shown in Fig. 1088. It is then raised by a crane, placed upon a low carriage, and removed to the casting-table. The outside of the cistern is carefully cleaned, and the glass skimmed with a broad copper sabre, to prevent any impurities from mixing with the glass on the casting-table. The cistern is then wound up to a sufficient height by means of a crane, and swung over the upper end of the casting-table, which has been heated by hot coals spread over it, and then wiped perfectly clean. The cistern being tilted over, a torrent of melted glass is suddenly poured out on the surface of the table: it is prevented from running off the sides by ribs of metal, *cc*, one of which is placed along the whole length of each side, their depth being the exact measure which is to be given to the thickness of the glass. When the cistern has been emptied, a massive copper cylinder, R, 3 feet in diameter, extending entirely across the table, and resting on the side-ribs, is set in motion, and spreads the glass out into a sheet of uniform breadth

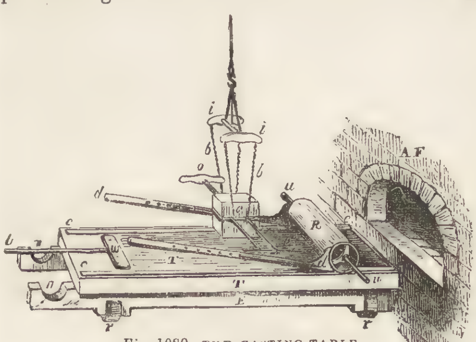


Fig. 1089. THE CASTING-TABLE.

and thickness. The pouring out of the glass is a grand sight, and the variety of colours exhibited by the plate immediately after the roller has passed over it is beautiful to behold. In order to remove all impurity from the casting-slab, a washer *w* is drawn immediately in front of the fluid glass; the excess of glass pours over the front edge into a trough filled with water: the roller then passes off the slab, and is received in the grooves *n n*. The casting is then cleared of any redundancy at the sides; a thick flange of the still soft glass is turned up at the end at *l*; and when this flange has become somewhat rigid, a rake-shaped iron is applied to it, and the plate is forced forward into the annealing-oven, or thrust upon a wooden platform moving on wheels, and so conveyed to the oven, where it remains about five days, in a horizontal position, exposed to a gradually diminishing temperature.[1]

Grinding and polishing. The plate being still hot and yielding when it is slid into the oven, takes an impression of the bricks of the oven upon which it rests, while the upper surface is generally made smooth and bright from the action of the fire, but it is not flat. The plates as they come out of the annealing-furnace are about ½ inch thick, of an irregular mottled appearance. They are carefully examined, to see whether the glass is sufficiently free from defects to admit of forming large plates, which, of course, have a much greater comparative value than small ones. If the defects are such as cannot be removed by grinding, the plate must be cut up into smaller plates, so that the defective portions may be rejected. The plates having been squared, next undergo the processes of grinding and polishing. These were formerly done by hand, but of late years this laborious work is almost entirely performed by machinery. The first object is to produce a level surface, which is done by grinding one plate upon another, a rough or rolled surface being opposed to the comparatively smooth or casting-plate surface. The grinding machines for large plates are arranged in pairs consisting of two benches of stone, 15 feet long, 8 feet wide, and 18 inches high. On the surface of each bench one or more plates of glass are imbedded in plaster-of-Paris, close together, and quite level. Other plates of glass are cemented upon the lower faces of two swing tables or runners, which are made to traverse over the fixed beds by appropriate machinery, in such a way that each runner is made to rotate around its own axis, and by a combination of two movements to change continually the relative position of the fixed bench and runner. Such an arrangement tends to the mutual correction of the two surfaces of the glass, and greatly assists the equal distribution of the sand and water. All the irregularities of the surface are first ground out with sharp river-sand, which has been washed and sifted into three sizes: the sand and water are thrown on by hand from time to time. When the plates have been ground quite flat, the finer sand is employed: this is followed by one finer still, which removes the scratches made by the coarser. The plates of glass are well washed between every change of sand, and when one side has been ground, the plates are reversed and the other sides ground.

(1) It has been proposed to form plate-glass by stamping, instead of rolling, between two metallic plates. Small plates are fluted or chequered on their surface by means of a steam-hammer, hydraulic press, or rollers arranged between two furnaces, one of which is similar to the flatting-furnace: the other is the annealing-furnace.

When the plates become sufficiently smooth to require the application of emery, there is a tendency to cohesion between the surfaces, which, travelling over each other with moderate velocity, produce so much friction that one surface will frequently tear the glass from the other. Hence it has not been thought safe to trust the next process, namely, the *smoothing*, to machinery, and hand labour has been employed. Lately, however, machinery invented by Mr. Blake, of the Thames Plate-glass Works, has been introduced. The Editor has seen it in action, and it appears to answer the purpose admirably; its object being to imitate the motions of the arms and legs of the persons employed in smoothing. The following is the method by hand. The plates are put upon flat stone benches about 2 feet high, covered with wet canvas, which serves to hold them firmly. The surface of each plate is sprinkled with emery and water, and a small plate is usually used as a grinder or runner; but if the plates be large, a few flat lead weights, of about 14 lbs. each, are put on the runner near the middle, to distribute the pressure uniformly, and the runner is made to traverse with a swinging rotatory stroke: each stroke is made to follow a slightly different path from the preceding one, and the runner is gradually twisted round as the smoothing proceeds. In this way every part of the bed-plate and runner is exposed to an equal amount of grinding, and the emery is uniformly distributed. Young girls are employed on small plates; but the large ones, which require more dexterity, and a much larger amount of traverse, are smoothed by two women, who stand on opposite sides of the bench, and, placing their outstretched hands flat upon the runner, swing it with a kind of eccentric circular stroke. Women are said to perform this rude work better than men, on account of their superior delicacy of touch, which leads them to use the moderate degree of force required, and to detect and remove particles of grit amongst the emery. About three sizes of carefully washed emery are used; and between every size the plates, canvas, bench, and hands are thoroughly washed: the dress must also be quite clean, as any particle of grit would ruin the work, and require the smoothing to be recommenced. The fine emery last used gives a very smooth and partly polished surface.

The polishing is completed by rubbers, covered with thick felt, and worked by machinery. The plates of glass are embedded close together with their surfaces quite level upon movable platforms fixed upon a traversing bed. The rubbers, which measure 8 by 6 inches each, are attached, 1 foot asunder, to reciprocating carriages, which drag the rubbers backwards and forwards over the surface of the glass, while the latter traverses beneath the rubbers a space equal to the distance between the two lines of rubbers, so as to expose all parts of the glass equally to their action. Each rubber is made to exert a pressure of about 15 lbs., by means of lead weights. The powder used for polishing is Venetian pink: this contains only a small portion of oxide of iron, mixed with earthy matter: it admits of being mixed with water, and thus reduces the friction, and prevents the glass becoming heated by the action of the rubbers. Tripoli, crocus, or putty-powder, used with water, are too active to produce a high polish on glass; but they may be employed dry for the last finish in hand-polishing. In polishing by machinery, dry powders must be avoided on account of the friction and heat evolved. Hand-polishing is very tedious, and is apt to produce a wavy appearance; hence machine-polished glass is to be preferred.[1] The machinery represented in Figs. 1090 to 1093 will convey a very good idea of that used in the grinding and polishing of ordinary plate-glass.

The grinding and polishing of the plates reduces their thickness as much as one-third, and in some cases one-half. Should the glass be defective, the polishing will only serve to heighten the defects; hence, a second and more careful examination and selection of the plates is now made. The defective ones are cut up into smaller plates, and these are polished again: the perfect ones are reserved for silvering, the process for which will be described presently.

To prevent or diminish the waste in the grinding, Mr. Bessemer has materially altered the whole of the arrangements of this manufacture. The furnace and the pots of glass are so arranged, that each pot, as soon as its contents are in a fit condition, is wheeled out of the furnace, and tilted, so as to pour the melted glass between two rollers placed at a certain distance apart, and kept cool by a current of water passing through them. In this way a uniform thickness of glass is ensured. The hot sheet of glass, on passing between these *forming* rollers, is received between two *finishing* rollers, and being closer together, and moving with accelerated speed, the glass is made smooth and flat. A fluted or a chequered surface can be given to the glass by the making rollers: such a surface is said to retain the sand used in grinding, and greatly to facilitate that operation. After the hot plate has passed between the second pair of rollers, it slides down a curved surface upon a flat table, and when sufficiently rigid by cooling, it is transferred to the annealing-kiln, which is heated by hot air, the direct action of the fuel being prevented. In polishing, the plate is secured to a slab of slate, and an endless band or strap of gutta percha, covered with felt and polishing material, is made to pass rapidly over the surface of the glass, in contact therewith: at the same time, the band is made to traverse slowly at right angles to the line of its motion.

Plate-glass is sometimes made by the blowing and flattening process already described. The irregularities of its surface arising from the imperfect action of the flattening process are, for the best glass, removed

(1) In Knapp's Technology, translated by Drs. Ronalds and Richardson, is an excellent article on Glass, in which the various modes of manufacture, as practised on the continent of Europe, are given. The translators have added a variety of details not to be found in the original, among which may be mentioned Messrs. Chance's and Messrs. Nicholson and Wadsworth's improvements in the manufacture of plate-glass. We must also refer to the admirable chapter on glass in the second volume of Dumas's "Chimie appliquée, &c." and to Gmelin's valuable notice in the third volume of his "Handbook of Chemistry."

by grinding and polishing. The moving parts of the grinding-machine employed for the purpose will be understood from Fig. 1090, in which the dotted lines represent the framing. This consists of continuous beams 1, 1, united by vertical parts 2, 2; and above is an axis 3, 3, carrying one pair of bevel-wheels, which turn the upright shaft 4 and its crank 5 to the right or left at pleasure. The pin of the crank 5 communicates a circular motion to that point of the

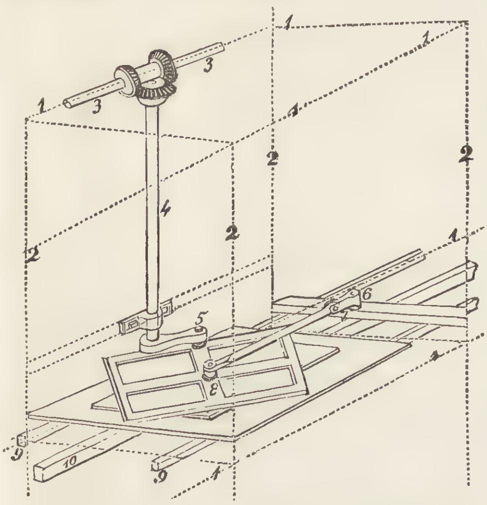


Fig. 1090. PRINCIPAL PARTS OF GRINDING-MACHINE.

moving-table to which it is attached, while the fixed radius bar 6, 7, 8 makes the centre of the table describe an arc about the point 6, and these two motions bring all parts of the running surface, in succession, in opposition to nearly every part of the lower bed: this bed rests on railway bars 9, 9, and is very slowly reciprocated to and fro by the bar 10, which sets a large number of machines in motion by means of a crank attached to it. The circle described by the crank 5 is about two-thirds of the length of the moving-table. The lower face of this table is covered with slate, upon which the glass is cemented: another sheet of glass is cemented upon the lower table, and the upper table is loaded with 4 or 8 weights, arranged so as to distribute the weight equally. Coarse emery and water are used for the grinding; and when the machines are used with finer emeries for smoothing, the whole apparatus is carefully washed. In some factories the plates of glass are smoothed by rubbing them upon one another by hand.

The sheet-glass having been ground flat and smoothed, is polished by machinery, the principle of which is roughly illustrated by the following figures. 1, 1, Figs. 1091, 1093, is the main shaft, extending throughout the length of the building, and having for every row of machines one double and two single cranks, which, by means of connecting-rods, move the two long central beams 2, 2 to the right, and at the same time the two exterior beams 2′, 2′ to the left. The travelling beams, or rods, carry rubbers 3, 3, about 12 by 5 inches on the face, and covered with leather; they are suspended by a joint to the loaded levers 4, 4′, Fig. 1092, which press them on the glass.

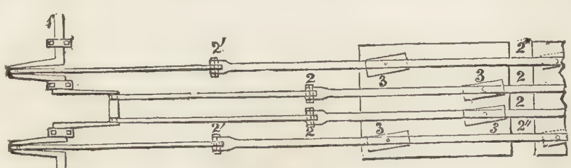


Fig. 1091.

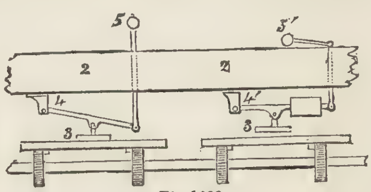


Fig. 1092.

The joint which unites 4 and 5 is situated in a mortice of the long travelling beam 2. In order to raise the cushion from the glass and throw it out of work, the piece 5 is raised and laid down in the position 5′, which brings the lever 4 into the position 4′. The rubbers all assume an inclined position in consequence of the several tables which carry the glass having a very slow transverse motion, which is brought about in the following manner:—The main shaft 1, 1, communicates with a pair of sliding bevel-wheels 6, 6, Fig. 1093; these through 7 move the tangent screw 8, and thence the worm-wheel 9, which latter, by the pair of bevel-wheels 10, 11, moves the long shaft carrying the line of pinions 12,12, one or two of which are under every table, and traverse the same by the aid of plain rollers 13, 13. A tumbling-bob is affixed to the table nearest the cranks and gear, by which the position of the pair of bevels 6, 6, is shifted to make the tables traverse first in the one and then in the opposite direction.

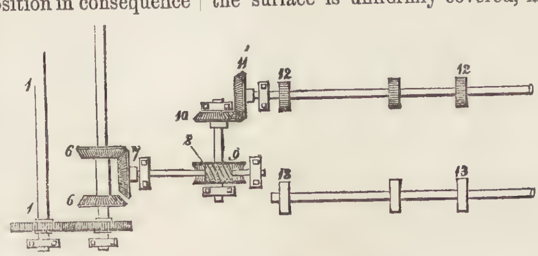


Fig. 1093.

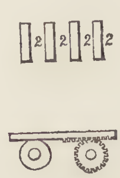


Fig. 1094.

Silvering.—A leaf of tin foil of larger dimensions than the plate to be silvered is spread out upon the silvering table, and mercury brushed over it. When the surface is uniformly covered, more quicksilver is added, so as to attain a height of 2 or 3 lines; the coating of oxide is removed with a wooden rod, and a brilliant surface produced. The plate of glass is pushed slowly forward from the side, with the longest edge foremost, and dipping below the surface of the mercury so as completely to exclude the air.

In this way the glass is brought into contact with the metal, and a brilliant surface produced. The plate may now be said to be floating on a bed of mercury. To get rid of the excess of metal the mirror is loaded with weights, and the table inclined 10° or 12°, when the mercury flows away. A further portion is got rid of by setting the plate up on edge, and in the course of 3 or 4 weeks a dry permanent coating of tin amalgam is left on the glass.

This method has many objections: the vapour of mercury is poisonous to the workman; the plates are liable to fracture from the heavy load placed upon them; and when set up on edge, drops of mercury sometimes trickle down, carrying the amalgam with them, thus rendering it necessary to re-silver the whole mirror. Moreover, the amalgam is liable to spoil by crystallization or carriage. Mr. Drayton's method is free from these defects. His *silvering fluid* is obtained by mixing ammonia with nitrate of silver, filtering the mixture, and adding to it an alcoholic solution of oil of cassia; (1 oz. nitrate of silver, 3 oz. of alcohol of 87 per cent., and 20 to 30 drops of oil of cassia, may be employed.) This fluid will, on the addition of a *reducing liquid* consisting of 1 part oil of cloves in 3 parts alcohol, deposit bright metallic silver. The glass to be silvered is made perfectly clean, and is surrounded by a rim of putty: a layer of silvering fluid, to the depth of 1 or 2 lines, is then poured upon it. The addition of the oil of cloves solution causes a film of brilliant metallic silver to attach itself firmly to the surface of the glass. The reduction should be slow; for which purpose a very small proportion of the reducing liquid is used; from 6 to 12 drops are sufficient to precipitate 4½ ounces of the solution of silver, and the film of metal is so thin that a square foot of it weighs only from 12 to 18 grains. The action of the volatile oil is to deoxidize the oxide of silver; while the nitric acid, set free, combines with the ammonia.

It is not easy to obtain by this process a perfectly clear unspotted surface. The dark colour of the coating, giving a certain black effect to the mirror, is also a disadvantage. This black appearance is due to the perfection of the silver coating, and the precision with which it reflects the rays of light, so that very few rays reach the eye unless the incident angle be very small, as when a person is standing opposite, or nearly opposite, the mirror. Whereas, the ordinary coating of tin amalgam is crystalline in its character; and although the surface in contact with the glass may appear to be homogeneous in character, yet every square inch of it is really composed of a multitude of crystals, which scatter the light, and reflect it to the eye in almost any position in which the observer may happen to be. It has been proposed by Vohl[1] to form the silver coating for small surfaces, the interior of glass balls, &c., by dissolving gun-cotton, or the explosive substance from sugar, mannite, &c., in caustic potash, by the aid of heat; to add to the brown solution a few drops of nitrate of silver, and then ammonia, until the precipitated oxide of silver is redissolved: it is then to be heated in a water-bath, when, at a certain point of the process, the mixture assumes a blackish brown colour, froths up, and all the silver becomes deposited upon the surface in the form of a mirror, which is said to be more brilliant than that produced by means of ethereal oils.

(1) Liebig and Kopp: "Annual Report of the Progress of Chemistry," vol. iii. 1849.

Mr. Drayton now employs a mixture prepared from 1 part solution of ammonia, 2 parts nitrate of silver, 3 parts water, and 3 of alcohol: this solution is filtered, and mixed with $\frac{1}{4}$th part of grape sugar dissolved in weak spirit.

A few years ago Dr. Faraday gave a lecture on this subject at the Royal Institution. The following was one of the illustrations. Two large plates of glass were mounted in a frame about an inch apart, the bottom and ends being closed with strips of glass, thus forming a long, narrow, transparent box. Before the lecture this was filled with silvering fluid, so that persons on the seats near the lecture-table could see persons on the opposite seats through the silvering fluid. On pouring some of the reducing liquid into the box, the glass sides became silvered, so that those persons who looked at each other through the fluid now saw their own faces reflected.

Section IX.—Coloured Glass.

All the varieties of glass, and most saline bodies of a vitreous character, such as borax, admit of being coloured by metallic oxides. Most of the colouring oxides afford more brilliant tints with clear white glass made of potash and lime than with those containing oxide of lead: in a few cases, however, lead-glass is to be preferred. The colouring metals are not always added to the glass in the form of oxides: silver is sometimes used in the form of chloride, or even in the metallic state; the colouring metals, however, in the glass are in the state of oxide, in combination with silicic acid.

The art of colouring glass is of early date; indeed, it seems to have been far more easy for the early nations to produce coloured glass than the pure white glass of modern times. The beads found in Egyptian mummies are specimens of true glass coloured by metallic oxides.

The colouring oxide must be intimately mixed with the glass, and both be completely fused. Glass vessels and panes for windows are often coloured merely on the surface, the body consisting of ordinary colourless glass. In forming this, the glass-blower collects the proper quantity of colourless glass on the end of his blowing iron, rolls it upon the marver, and when sufficiently set, dips it for a moment into a pot of melted coloured-glass, and blows out the two together into a cylinder or globe, which is flatted or flashed out in the ordinary manner. Vessels of flint-glass are coloured on the outside in a similar manner, and colourless facets produced by cutting through the layer of coloured glass into the substratum of colourless glass.

In stained and painted glass the metallic oxide is mixed with vitreous bodies capable of easy fusion,

and with fluid vehicles, such as oil of turpentine. These are applied to the surface of the pane with brushes, as in ordinary landscape or figure painting; but the difficulties of the artist on glass are of a much more formidable character than those of the artist on canvas: he must be as good an artist as the latter, but he must also have the faculty of seeing his effects as they will appear after the firing, and not as he lays them on; for the colouring oxides which he employs, especially when mixed up in their fluid vehicles, are dark, dirty, and disagreeable in colour, and have nothing in common with the bright and beautiful effects which we admire in a stained glass window. Where the same figure or pattern is to be repeated many times, it is in some cases printed on the glass with a gentle pressure from an engraved metallic plate, or wooden block, boiled oil being used as the vehicle for the colouring oxide. The pane, having been prepared either by painting or printing, is exposed in an oven or muffle to a temperature sufficient to fuse the vitreous flux and dissolve the colouring material. The glass selected for the purpose of the stainer should be clear and colourless, in order to bring out the colours well; and difficult of fusion, so that the flux and metallic oxide may form a coloured glass upon its surface before it shows any tendency itself to fuse. A glass containing a small proportion of alkali, such as crown-glass, is fit for the purpose.

At the meeting of the British Association at Birmingham, in September, 1849, M. Bontemps brought forward some important practical points connected with the coloured ornamentation of glass and porcelain. In the first place, it was shown that all the colours of the prismatic spectrum may be imparted to glass by means of oxide of iron, in varying proportions, and by the agency of different degrees of heat; the conclusion being that all the colours are produced in their natural disposition in proportion to the increase of temperature. Similar phenomena were observed with the oxide of manganese. If glass coloured with this oxide remain too long in the melting-pot or the annealing-kiln, the *purple* tint turns first to a light *brownish red*, then to *yellow*, and afterwards to *green*. White glass in which a small proportion of manganese has been used is liable to become light yellow by exposure to the solar rays, and in certain kinds of window-glass it turns pink or purple by a similar exposure. Such changes also take place in the annealing-oven. In these cases, M. Bontemps supposes light to be the active agent, and not a change in the oxidation of the metal. A series of chromatic changes of a similar character were observed with the oxides of copper; the colours being in like manner regulated by the heat to which the glass was exposed. It was found that silver, although with less intensity, exhibited the same phenomena; and gold, although usually employed for the purpose of imparting varieties of red, was found, by various degrees of heating at a high temperature, and recasting several times, to give a great many tints, varying from *blue* to *pink*, *red*, *opaque yellow*, and *green*. Charcoal in excess in a mixture of silico-alkaline glass, gives a yellow colour, which is not so bright as the yellow from silver, and this yellow colour may be turned to a dark red by a second fire. M. Bontemps is disposed to refer these chromatic changes to variations in molecular arrangement, rather than in chemical composition.

This important series of observations cannot be said to be altogether new. Somewhat analogous effects have long been known to belong to gold and copper. For example:—Gold produces a beautiful red glass. After fusion this glass is colourless; but when heated not above a red-heat, it becomes of a bright red colour. According to Rose, the gold is in a state of protoxide, which forms a colourless silicate by fusion, but when re-heated a little below the temperature necessary to form it, some portion of the protoxide is set free. This protoxide, disseminated in small quantity in a state of extreme division, is supposed to give the red colour. When too much heated, the red becomes brown, which may be due to a partial reduction of the oxide, metallic gold being set free. A similar effect occurs in glass coloured by copper. A glass containing protoxide of copper is colourless after fusion, but it becomes green after heating, owing to the oxide set free. Auriferous glass may be formed from 46 lbs. of quartz, 12 of borax, 12 of nitre, 1 of minium, and 1 of arsenious acid: these are moistened with a solution of 8 ducats of gold in aqua regia, and then fused.

Glass, porcelain, and earthenware are ornamented by a process similar to the above, by covering the vessel or plate to be coloured with a thin layer of some adhesive matter, as essence of lavender, and carefully dusting on this a finely-powdered mixture of the colouring oxide with the proper flux. The colour is then fixed by firing. To obtain a coloured design the surface of the glass may be printed with adhesive varnish from an engraved block, the oxide and flux are then dusted on, and the powder which does not adhere to the varnish is blown off with a pair of bellows previous to firing; or the glass may be entirely covered with varnish, and the powder be sprinkled upon it through a perforated screen or open fabric, such as lace, applied to the surface.[1]

The varieties of coloured ornamental glass are very numerous, and many of them are derived from the Venetians. The *Venetian ball* consists of a number of pieces of filigree glass packed into a pocket of transparent colourless glass, which is adhesively collapsed upon the interior mass by sucking up, thus allowing the outward pressure of the atmosphere to act upon it. The *Venetian filigree* consists of plain and coloured enamel. Canes or sticks of glass are arranged round the interior of a mould: a solid ball of transparent flint-glass is then put in, and when the canes have adhered to it, the ball is re-heated, marvered, covered with a gathering

(1) The reader interested in this part of the subject is referred to two small treatises contained in Weale's Rudimentary Series, entitled, "An Essay on the Art of Painting on Glass, from the German of Emanuel Otto Fromberg," and "Treatise on the Art of Painting on Glass, or Glass-staining, comprising directions for preparing the pigments and fluxes, for laying them upon the glass, and for firing or burning in the colours. From the German of Dr. M. A. Gessart." The latter work contains an Appendix on the Art of Enamelling

of white glass, and the whole is then worked into a vessel. Spiral stems for wine-glasses, &c. are sometimes made in a similar way. *Millefiore glass* (the manufacture of which has recently been revived by M. Bontemps) is formed by fusing together a number of tubes of various colours, sections representing stars, flowers, &c.: slices of these tubes are embedded in white transparent glass, the whole forming a pleasing ornament which may be used as a letter-weight. Many of the patterns are, however, very tasteless. *Mosaic glass* is produced by small rods of variously coloured opaque or transparent glass of uniform lengths, ranged so that the ends may form patterns. The whole being properly secured, slices are cut at right angles to the length, whereby the pattern is multiplied. *Smetz glass* is formed by fusing lengths of coloured glass into each other, so that the section shall resemble carnelian and the agates. *Vitro di trino* is a sort of lace-work, formed by intersecting lines of white enamel or transparent glass, the centre of each mesh being occupied by a bubble of air. *Frosted glass* is formed by plunging the vessel after it has been blown, and while still hot, into cold water; re-heating and re-blowing it; when it appears to be covered with fractures, although it is quite sound and sonorous. The art of making this glass was kept secret by the Venetians, but was re-discovered by Mr. Pellatt a few years ago.

Aventurine Glass is a glass of a brownish colour interspersed with small spangles which give it a peculiar shining appearance. The method of manufacture was long kept secret. Gahn observed that the spangles consist of metallic copper, crystallized in the form of flat segments of a regular octohedron. Fremy and Clemandot succeeded in preparing this glass, by fusing together for 12 hours a mixture of 300 parts pounded glass, 40 parts of copper scales, and 80 parts of iron scales, and afterwards cooling the mixture slowly. The glass obtained was somewhat dull, but it contained copper diffused through it in octohedral crystals.

To Mr. Pellatt also do we owe the invention of the method of ornamenting glass with delicate white Argentine incrustations of dry porcelain clay, cemented into the solid glass. The figures, made thoroughly dry, are placed on a red-hot bulb of flint-glass, and immediately covered with a thin layer of very fluid glass, so as completely to enclose the incrustation. The polishing of the exterior layer gives the white figure a silvery appearance. The incrustation may of course be coloured before being applied to the glass. Flint-glass vessels with coloured enamel figures on the outside, are sometimes prepared by placing the enamel figures in their proper position in the mould in which the glass is blown. The hot glass firmly cements the figures to the surface.

Section X.—Bottle-Glass.

This is the coarsest variety of glass that is manufactured. Formerly, when the duty was only one-eighth that of flint, the law required that wine and beer-bottles should be made of the coarsest materials, such as soap-boilers' waste, and common river or sea sand. Now that the manufacturer is released from the onerous infliction of the excise, he acts to a certain extent according to its old traditions. His glass is not very uniform in character, nor are his materials very pure. But theoretically the basis of bottle-glass is a triple silicate of soda, alumina and lime. The place of a portion of the lime is generally occupied by magnesia and protoxide of iron, and part of the alumina by peroxide of iron. The alumina is in the form of clay. The raw materials are fritted in arches attached to the principal furnace. A very high temperature is required for vitrification, on account of the small proportion of alkali. In 18 or 20 hours the vitrification is generally complete; the glass-gall is skimmed off, and the glass cooled down to the blowing consistency. A wine-bottle is formed in a cast-iron or brass mould, as in the case of flint-glass bottles, and in English wine-bottles the mark of the mould is generally too prominent. Large round bottles are blown without the use of a mould, and when of considerable size, as in the case of carboys for sulphuric acid, the aid of steam is called in; the man spirts a mouthful of water into the interior of the globe which he is blowing, and placing his thumb over the mouth of the blowing tube the water flashes into steam, the elastic force of which acting equally in all directions distends the glass to the required size of the carboy.

Wine bottles require care in the mode of manufacture, according to the class of wine which they are to contain. If the lime or other alkali of the bottles be in excess or not chemically combined, and the wine be of an acid character, the bottle will be slowly disintegrated. If dilute sulphuric acid be kept for a length of time in English-made wine bottles, it will often happen that the interior of some of them will become covered with pustules growing out into the bottle, in consequence of the acid combining with the lime in different points, where it is not chemically combined with the other materials. In this way the bottles may in course of time be drilled through and the contents emptied. We have examined bottles in all these conditions. Bottles containing a fermenting wine should be very strong. The wine-growers of Champagne lose 15, 20, and even 30 per cent. of bottles of wine from bursting by internal pressure. In the Great Exhibition, bottles were exhibited by MM. de Violaine, of Vauxrôts near Soissons: these bottles are much used in Champagne, and it is said that they are all calculated to resist an internal pressure of 25 to 35 atmospheres, (*i.e.* from 25 to 35 times 15 pounds on every square inch of internal surface,) as proved by a machine constructed for the purpose.

Section XI.—Statistics.

Glass being now free from the trammels of the Excise, we are happily spared the disagreeable task of pointing out the national and individual loss and injury arising from the imposition. We hope before long to see every other description of British industry set free from all Government interference. Our

future progress requires it, and we believe that it would be greatly to the advantage of all classes to pay taxes on property rather than have them levied on industry.

Great Britain possesses all, or nearly all the materials required for glass-making, and has abundance of cheap fuel. Hence she possesses peculiar advantages for the manufacture. It would therefore be supposed, that with a drawback on her exports she would long since have supplied a large portion of the world with glass. That such is not the case arises from the fact, that the excise laws did not allow us to enter into fair competition with other nations, or so to improve the manufacture at home, as to keep pace with an increasing population. Thus, according to Mr. Porter,[1] in 1801, with a population of 16 millions, the quantity of glass used was 325,529 cwts., and in 1833, with a population of 25 millions, the quantity was no more than 363,468 cwts.; an increase of less than one-eighth, while the population had increased in the proportion of one-half. Between 1827 and 1845, in which latter year the excise duty was repealed, some improvement took place in the modes of manufacture, so that articles in common use were within that period reduced in price as much as 25 per cent.

In the years 1849 and 1850, the declared values of the exports in glass of British manufacture were as follows:—

	1849.	1850.
Flint-glass	£84,964	£106,191
Window glass	24,196	20,079
Bottles, green or common	131,887	163,759
Plate-glass	13,303	18,317
Total	£254,350	£308,346

In 1844, the year before the duty was repealed, and with all the advantage of a drawback, our exports in glass were of the declared value of £26,694 only.

GLAUBER SALT, named after its celebrated discoverer, who, although an alchemist, enriched true chemistry with a number of valuable discoveries. Thus, he discovered muriatic acid by the action of sulphuric acid on common salt, and from the residue of that operation he obtained Glauber-salt, or *sal-mirabile,* the sulphate of soda of modern chemistry. See SODA.

GLAZING is the art of fixing glass in the frames of windows. The glass is made secure by means of putty, which consists of whitening and linseed oil. The glass is cut by means of the diamond, as fully described under CARBON, page 310. Ordinary crown-glass is slightly convex on one surface and concave on the other. In glazing windows the effect is much more pleasing to the eye when the convex surface is turned outwards, than when the reverse is the case. British plate or flatted glass is now taking the place of crown-glass, the larger sheets of which are likely to be much in request since our windows as well as our glass have been happily freed from taxation. For GLAZING, see also POTTERY and PORCELAIN.

(1) Progress of the Nation. 8vo. London, 1847.

GLOVES. The manufacture of gloves is not by any means of recent date; but the ancient use of this article of dress was rare and occasional, whereas the modern use is common and almost universal. The ancient Persians wore gloves, and this was cited by Xenophon as a proof of their effeminacy. The father of Ulysses, according to Homer, wore gloves while working in his garden, to protect his hands from thorns. The Romans wore gloves, and were railed at by philosophers for so doing. In the first century of the Christian era it was noted as "shameful that persons in perfect health should clothe their hands and their feet with soft and hairy coverings." Nevertheless, the use of gloves progressed in the world, as we find from various regulations concerning them. They also came to bear part in solemn ceremonials. Possession of lands or dignities was conferred by delivering a glove; deprivation was signified by taking away gloves; challenges were offered by throwing down gloves. Their value in the colder climates caused the familiar use of gloves to go on increasing, but they do not appear to have been adopted in English female dress until after the Reformation. The gloves worn by ladies in the reign of Queen Anne were richly worked and embroidered. Our French neighbours have sought to connect the history of gloves with religion, by affirming that St. Anne, the mother of the Virgin Mary, was a knitter of gloves, and that on account of this her occupation, workpeople of this class have placed themselves under her protection, so that she is invoked to this day in the principal seats of this manufacture in France, and especially at Grenoble, where the feast of St. Anne is observed with great solemnity. This account of St. Anne's employments is prefaced in our French authority by the words, "Scripture informs us that St. Anne," &c.; but it would be a vain attempt to seek for such information in Holy Writ.

The principal materials used in the glove-manufacture are leather, silk, cotton, and worsted. Leather, when prepared for this purpose, undergoes a much lighter dressing than when prepared for boots and shoes. The great seat of the glove-trade in England is the city of Worcester and its neighbourhood. Prepared leathers are frequently sent to that city from Bermondsey, and the processes of cutting them up into the proper shape and size, and distributing them to the work-women for sewing, form the employment of numerous firms. France has long been celebrated for its glove-manufactures; but previous to the year 1825 the importation of leather gloves into England was forbidden under heavy penalties. While this prohibition lasted, English gloves were very inferior in quality and high in price; but on its removal in that year, and the admission of foreign gloves at a fixed duty, the improvement in our manufacture was marked and rapid, while the sale of English goods was not diminished. There are certain particulars, however, in which the French continue to excel us greatly in the manufacture of gloves. Some of these will be noticed in the following sketch of the processes.

The first operation in glove-making is to stretch out

on a piece of marble, and render uniform with a blunt knife, (shown in Fig. 1095, No. 1,) the surface of the skin of which the gloves are to be made; after which it is to be reduced into pieces of convenient length and width, without cutting the material to waste. Before cutting, however, the skin is made damp, either by rubbing it with a wet cloth, or by putting it in a damp place. It is then sounded, and examined with a view to the discovery of faults or blemishes, so that they may be avoided in cutting out, or at least that they may be so placed as to be unimportant. The skin is then placed so that the width of the glove may be taken across its narrow part. There are regular scales of sizes for men's and women's gloves, and for the width of the thumb-pieces, which are cut out at the same time, and are proportioned to the particular size required. In order to cut the skin to the best advantage, it is stretched from time to time by pulling it at the edges, between the thumb and the knife. When it has been thus elongated and spread out to the utmost, the actual cutting process commences: and here it is, we are told, that the French glove-makers have a great advantage over the English. The former are exceedingly skilful in turning the skins to good account. In cutting up a dozen skins of equal size, a Frenchman will generally manage to get one or two pairs of gloves over and above the number which an Englishman can cut out from the same skins; and these, not inferior, or scanty, but well and handsomely shaped as the rest. This clever and adroit manipulation of the leather is an object of great importance in France, where not less than 375,000 dozens of skins of all kinds are cut up into gloves every year. The shape of the gloves to be cut out is not the only thing to be attended to; great care must be taken that the same shade of colour prevails throughout each pair, for it frequently happens that there are cloudy spots and gradations of colour in the skin, which would be destructive of beauty and good effect. The

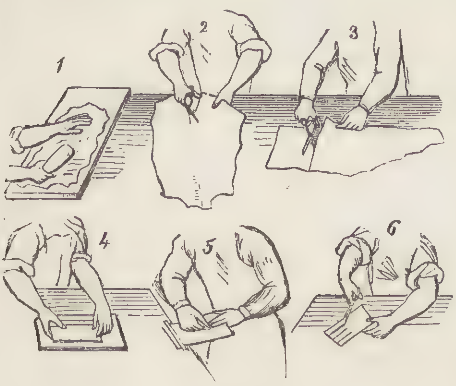


Fig. 1095.

first operation is to cut the skin longitudinally into two parts, as in No. 2. A piece being divided of the proper width and length for the hand, as in No. 3, is spread out and adjusted, and then carefully folded in two longitudinally, in such a way that a little more width shall be allowed for the back than for the front of the glove. See No. 4. This is necessary, in order that the thumb may have room to move freely, and that there may be proper freedom to the back of the hand when the hand is closed. The want of sufficient allowance in this respect is soon proved by the splitting of the backs, which is such a frequent and annoying occurrence with cheap gloves. The next thing is to make, at fixed distances apart, the three longitudinal cuts which are to form the four fingers. The workman makes his own middle finger a measure for the length of the principal cleft in a man's glove, allowing a little over for the taking up of the leather in working. See No. 5. The width apart of the clefts is regulated by the fact that the first and fourth fingers will have gussets or strips of leather inserted only on their inner sides, while the middle and third fingers will have gussets on both sides. These gussets are carefully cut out, as are the thumb-pieces, from the pieces of the skin remaining over and above from the cutting of the gloves.

Unless economy is used with all these pieces, it will often happen that a new skin of leather will have to be cut into for the inferior parts, and thus waste will ensue. The forms of the thumb-piece and gussets are shown at *a* and *c* in Fig. 1096. To facilitate the movement of the fingers, there are also small angular pieces, *d*, inserted at the base of the finger, towards the palm

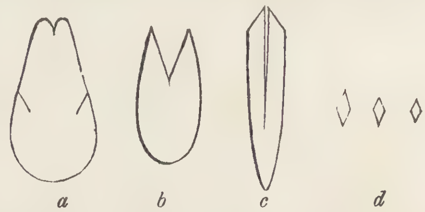


Fig. 1096.

of the hand. No small skill is required in cutting out the hole in each glove which is to be filled by the thumb-piece. There is a prescribed, and slightly oblique position in which this hole is to be made, (see No. 6, Fig. 1095,) but as it is necessary it should correspond in form with the peculiar shape of the thumb-piece, it is perhaps the most delicate part of the whole operation to give the exact turn of the scissors which shall produce the desired result. A defect here is often visible in badly made gloves: either the hole is too small for the thumb-piece, and the latter is slightly puckered in putting it in, or it is too large, and the contrary plan has to be resorted to, or it is altogether badly shaped, causing an uncomfortable strain, and a speedy fracture. The form of the aperture varies in different workshops, but the general shape is somewhat as represented at *b*, Fig. 1096. The increasing employment of machinery in the cutting out of gloves promotes uniformity. At the Great Exhibition a French manufacturer (Jouvin, *Boulevard Poissonière*, Paris) exhibited a number of punches for cutting out gloves.

The glove, which now begins to assume its proper form, is next to have the fingers rounded to the proper length, and the back embroidered, when it is ready to be sewed. The sewing of gloves requires more care than that of any other material, especially

at the extremities of the fingers, where the joins must be perfectly accurate, and where the closeness of the sewing may, without great care, tear away the delicate leather of the glove. There is a particular order to be observed in the sewing of gloves. The first care is to get the thumb-piece nicely put in, and to correct, as well as may be, any little irregularity which may occur in the fitting of that piece to its place. The outer part is first sewed, arriving afterwards at the tongue-piece which adapts it to the movements of the hand. When this is completed, the glove is folded together, and the long seam is commenced, which reaches from the wrist to the top of the little finger. A gusset is then taken and inserted, the sewing being carried along the outer seam of that and the rest of the gussets, towards the back of the hand. When in this way the fore-finger is arrived at, the gussets are shaped at the top, and the sewing of the inner seam towards the palm of the hand is commenced, the little triangular pieces being duly inserted at the base, for the sake of giving greater freedom to the action of the fingers. All that remains to be done is to make a strong hem round the wrist, and to add a button and button-hole, if it be a glove of the description requiring it. The sewing of gloves may also be effected by machinery.

The following description applies to an ingenious machine largely employed in the sewing of gloves in Paris. Fig. 1097 gives a side-view of it, ready for action. It consists of an iron vice A A made fast to the edge of a bench or table B, by a thumb-screw C, armed with a cramp which lays hold of the wood. The two jaws of the vice have their upper portions made of brass, and tipped with a kind of comb of the same metal. The teeth of this comb, only one-twelfth of an inch long, are perfectly regular and equal. Of the two jaws, composing the machine, one, D, is made fast to the foot A A, but the other, E, is movable upon the solid base of the machine, by means of a hinge at the point F. At I I are indicated the points of junction between the brass and the iron. At the bottom of the figure is a front view of the comb as it appears when mounted on the vice, to which it is secured by screws. The lever K corresponds by a stout wire, L, with a pedal pressed by the needle-woman's foot, whenever she wishes to separate the two jaws, in order to insert between them the parallel edges of the leather to be sewed. These being firmly fixed, the woman passes her needle successively through all the teeth of the comb, and is sure of making a regular seam in every direction, provided she is careful to make the needle graze along the bottom of the notches. As soon as one seam is finished, she presses the pedal with her foot, the jaws start asunder, and she adjusts another seam. The vices may be mounted with combs of various shapes, according to the nature of the work. This machine is the invention of an Englishman, and has obtained great praise among the best glove-makers of France.

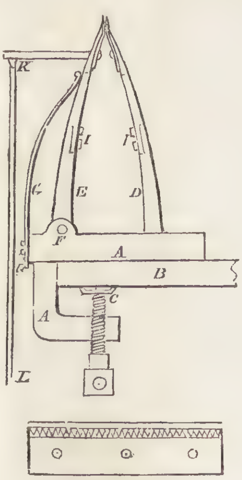


Fig. 1097.

In a machine for sewing and pointing leather gloves, patented by Mr. James Winter of Stoke-under-Hambdon, Somerset, an arrangement is made for readily removing the jaws of the vice, and adjusting others in their place. This effects a saving of time, for while one person is sewing, another can be preparing and placing the next seam. There are also various modifications of the comb, adapted to different methods of sewing and stitching the seams of gloves.

GLUCINA (G_2O_3), a rare earth, found in the emerald, beryl, and euclase. It resembles alumina, but is distinguished therefrom by its solubility when freshly precipitated in a cold solution of carbonate of ammonia, from which it is again thrown down on boiling. The salts of glucina have a *sweet* taste, whence its name, from γλυκύς.

GLUE. See Gelatine.

GLUTEN. See Bread, page 175.

GLYCERINE. See Candle, page 288.

GLYPTOGRAPHY. See Electro-Metallurgy, page 573.

GNEISS, a rock abounding in metallic treasures, and the oldest of the stratified rocks. It is composed of the same substances as granite, viz. quartz, mica, and felspar; but they are not in *granular* crystals, but in scales, so as to give the mass a slaty structure.

GOLD. This beautiful substance has been long ranked as the most precious, as it is also the most imperishable and easily worked of metals. It is more generally distributed than any other metal (iron only excepted); but, for the most part, it occurs in such minute quantities as either to escape notice, or not to be worth the pains of extraction. Until recent times, the search after this metal was one of the most precarious and disappointing of human pursuits, and its discovery frequently involved the ruin of the individual, either through the necessary outlay in the commencement of mining operations, or in the improvident habits which the prospect of sudden wealth was apt to induce. We learn from the only infallible source, that gold existed in that part of the earth's surface which was first prepared as the dwelling of man. So, likewise, in all his subsequent wanderings, gold became man's coveted possession, and tokens of its presence were from time to time discovered in nearly all lands. Yet so comparatively small were the gatherings of the precious metal, that in reckoning the average produce of all parts of the New and Old world for a series of years previous to 1847, it did not amount to the annual value of five millions sterling. In that year, however, the first of a series of discoveries was made, which led to a vast increase in the supply of gold, and to a complete reversal of old ideas respecting the prospects of the gold-hunter. These discoveries,

forming as they do the grand topic of interest at the present time, will first claim our attention.

In the map of North America, the long narrow peninsula of California, washed by the Pacific, and fenced in with rocky barriers, excited very little interest until the year 1847, when it rose into sudden importance as the El Dorado of modern times. In the greater portion of the mountainous ridge which protects the western coast of California, there are few important breaks or gaps, so that the valleys in the interior are in a great measure isolated; the more so, as an inner range of mountains, running in the same direction as the outer, (nearly north and south,) combines to shut up the particular district to which we refer. The most important opening in the coast-ridge occurs at a place called San Francisco, where the rivers of the interior find outlet in a noble harbour. Two important rivers, having an exactly opposite course, and each receiving the waters of many tributary streams, here unite to pour their waters into the Pacific. These rivers are the Sacramento, flowing from the north along the valley formed by mountain ranges, and the San Joaquim, flowing from the south along the same description of valley, enclosed by the Rocky Mountains on one side, and by the coast range on the other.

It was in September, 1847, that the first symptom of gold in this region was discovered, on the property of an intelligent Swiss emigrant, Captain Suter, who had become a wealthy settler on the banks of the Sacramento River, was possessed of large flocks and herds, owned trading vessels, and had built an important fort, called New Helvetia, for the defence of his property. The state of the country, and the absence of lawful authority, may be judged of by the fact, that he found it necessary to supply his fort with twelve pieces of artillery, and a garrison of seventy men.

It was in the course of the erection of saw-mills on this estate that Mr. Marshall, the contractor for the building of the same, observed glittering particles in the mud of the stream, and communicating the information to his intelligent employer, the value of these particles was quickly ascertained. The workpeople soon became aware of the discovery, and the town of San Francisco speedily yielded nearly its whole population in the exciting search for gold. The supply was beyond all expectation great, and the consequent rush of emigrants of all nations to share in the riches is well known. Various were the evils arising from this influx of strangers in a half-civilized country, and still more various were the prophecies of ill to the world at large. In England it was commonly thought that this sudden gold-harvest would demoralise industry, and throw the great machine of commerce out of order, and that, after all, the supply would be very soon exhausted. This last idea, however, has proved unfounded. Every new account from this wonderful coast seems to extend the range of the gold-seekers. Gold is found in the excavations of the mill-race, and in the mud of the river; accumulated in gulleys, and diffused over plains; set deep in quartz, or mixed with crumbling granite. "It was found in digging a well at San Francisco; and then, a hundred miles off, it was dropping from cliffs into the sea, and slowly settling through the sands of the shore. The searchers have to dig pits, to climb mountains, to turn rivers, to sink shafts, to run galleries, to uncover plains, to break, to crush, to roll, to shake, to wash, to amalgamate." One discovery quickly supplants another, and one set of implements quickly yields to another. At one time a rocking-machine for separating the gold was in great demand; but before our manufacturers could send out a supply, it was superseded by a cradle of ingenious construction. Then came crushing-mills of various kinds, for pounding the auriferous quartz of Mariposa. An immense amount of machinery has been sent out for this purpose, and will doubtless be turned to good account; but the most recent accounts from California speak of discoveries which offer gold without the use of tools or machines other than the common implements for turning up the soil; for the precious metal in this case lies in a soft greasy slate, easily to be crumbled between the fingers. The slate is thickly interspersed with extremely fine particles of gold, which are separated by means of quicksilver. At a spot appropriately named Mount Ophir, fine specimens have been met with, of "soft clay and slate saturated with gold, small particles and large lumps." These treasures lie from 10 to 30 feet below the surface, so that a great deal of top dirt has to be thrown up before the slate is reached. Seven Mexicans, who made this discovery, and kept their secret eight days, made in that short time 217,000 dollars. One lump might yield three dollars, another twelve dollars, and so on. Other searchers, from a shaft twenty feet deep, obtained the soft clayey slate in buckets, and found from eight to twelve dollars' worth of gold in each bucket. This new discovery comes within the limits of the "diggings," and falls under what is called "placer" law; that is, every man who comes may claim his thirty feet square, and set to work as he pleases, without asking the landowner's leave. If he wanted to plant mills, and make expensive mining works, he would have to obtain a grant of the soil. A great number of persons are already congregated in the new diggings, and a flood of gold seems to threaten the European market. From the great Californian field of enterprise, thirty millions of gold have already found their way into the commercial world, without producing any very striking or marked effects; but if this rate of produce continues, there must eventually be produced corresponding alterations in monetary matters.

While the attention of the whole world was directed to the golden land of California, a new announcement was made, in which England had a special interest; namely, that gold was discovered in her Australian possessions. And certain it is that the year 1851, memorable to this country in many other respects, was also memorable from the fact that Australia then began to reveal her long-hidden treasures. The first discoveries were made near Bathurst, which is situated

upwards of a hundred miles west of Sydney, New South Wales. They are due to Mr. Stutchbury, a geologist employed by Government, and Mr. Hargraves, a gentleman who had long been familiar with the geology of the Blue Mountains. The latter washed out gold from several baskets of earth, and soon organized a body of persons to assist in his labours. Similar results to those in California soon followed; only that in this case the law afforded its protection to the gold-searchers, and the whole affair was early put under Government inspection. Gold was found with surprising facility: lumps of the pure metal were picked up; and a poor man, who went to the diggings with only a forked stick and an old frying-pan, raked up five pounds' worth of gold in half a day. Two thousand persons had speedily established themselves at the Ophir diggings, (for again we have the propitious name,) and one large specimen of pure gold had been found, weighing forty-six ounces. Meanwhile, a Government proclamation taught the people their relations to the mother country, as it respected the new discoveries: viz. that all gold-mines in the British dominions belong by law to the Crown; that no gold was to be removed from the leased lands without Government permission; and that licences were about to be granted to gold-seekers, at definite fees or royalties, and under definite arrangements. The fees amount to thirty shillings a-month.

But the Australian gold-field is not confined to a few rivers in the neighbourhood of Sydney and Bathurst. Wonderful news has reached England of deposits further south, which surpass all that has been told of Sydney, and even California. At a place called Buninyong, about eighty miles from Melbourne, and fifty from Geelong, eight feet square, instead of thirty feet square, of digging ground is supposed to be enough to make a person's fortune. One man had found fifteen hundred pounds' worth of gold in one week,—another man a thousand. A party of three men had met with twenty pounds' weight in one day, while another before breakfast raised thirteen pounds' weight. Thus Melbourne and Port Phillip are becoming even more attractive than Sydney. The whole neighbouring population were moving towards the gold district, and a far greater desertion of general employments had taken place than had been witnessed at Sydney. Hundreds of all classes were hastening to Buninyong, including labourers, mechanics, clerks, shopkeepers, merchants, and professional men. There was hardly any possibility of getting ships' crews; and the ship which first conveyed the intelligence to Bombay was only enabled to sail by obtaining her complement of men from among the seamen confined on short sentences in Melbourne gaol. Even that was attended with difficulty, for only six could be found who did not prefer stopping in confinement, on the chance of getting afterwards to the mines. A government escort had arrived with 17,000*l.*, and was to return for a further sum of 20,000*l.* The metal is found at considerable depths; and, in order to obtain it, "a hole is dug, ten or twenty feet deep, through black alluvial soil, sandy gravel, and clay of various colours, until a very thick substratum of pipe-clay is reached. Immediately above this is, in places, a stratum of chocolate-coloured clay, in which the gold is not only perceptible, but conspicuous; and one man sits in the hole and picks out the rich stuff with a knife, while his companions with a cradle work the earth which has been thrown out.

Thus we appear to have an abundant, accessible, and wide-spread supply of our own, in addition to the great gold-fields owned by America, and open to all emigrants. And it is impossible to say how many more gold-regions may now come to light, inviting the population of crowded Europe to new homes, and wider spheres of action. Many a swarm will be sent off from the parent hives, and many a new community will spring up in the gold-countries. Let us hope that, as the golden harvests have been bestowed on the only two free nations of the earth—the United States and the British Empire—their children will use the dangerous gift with discretion, remembering that wisdom "cannot be gotten for gold, neither shall silver be weighed for the price thereof."

In connexion with the Australian discoveries, it is a remarkable fact, that Sir R. Murchison foretold them in 1845, when he compared the eastern chain of Australian mountains with the Ural. In 1846, he even recommended the unemployed Cornish tin miners to emigrate to New South Wales, and dig for gold in the debris and drift of the Australian Cordilleras. In 1847, he received letters from speculators in Sydney and Adelaide, sending specimens of gold which they had sought and obtained in consequence of his writings; whereon Sir R. Murchison wrote to Earl Grey, informing him that his anticipations were about to be realized in a manner which might operate a great change in the colony. His views were further embodied in the *Quarterly Review*, 1851. The Rev. W. B. Clarke, also, in examining the geological structure of the Blue Mountains of Eastern Australia, as early as 1841, "was attracted by the plutonic and metamorphic character of the axis of the range, and by the presence of gold in the quartzites and in the detrital accumulations derived from the axial formations, evidence being afforded of the existence of gold within eighty and sixty miles of Sydney." By subsequent researches, Mr. Clarke was convinced that "copper, lead, and gold are in considerable abundance in the schists and quartzites of the Cordillera" (Blue Mountains).

These discoveries, though of paramount interest, must not make us forgetful of the state of gold-mines previous to 1847. Let us first describe those of Europe. There are not many countries totally without traditions of gold, and in the British Isles, these have at various times appeared to promise substantial results. In the alluvial soil of Leadhills in Scotland extensive washings for gold were carried on in the time of Queen Elizabeth. The precious metal was also found to occur at Glen Turret in Perthshire, and at Cumberhead in Lanarkshire. The stream-works of Cornwall also yielded gold, and towards the

close of the last century the most promising accounts were given of gold in Ireland. In fact, the peasantry in the neighbourhood of Ballinavalley River, County Wicklow, did gather, in the course of two months, an amount of gold for which 10,000*l.* were paid; but on the government undertaking the search, it proved that the supply was very soon exhausted, considerably less than four thousand pounds' worth being collected in the course of two years. This did not pay the necessary expenses, and the works were abandoned. The gold, as at first collected by the people, occurred in massive lumps, and in small pieces, down to the minutest grain. Pieces of 7, 9, 18, and 22 ounces were found, and these occurred dispersed through a kind of stratum of clay, sand, and gravel, covered by soil which sometimes was of considerable depth, from 20 to 50 feet in the banks of streams. Recently, some energetic proceedings have been commenced, and workings established on a large scale for the discovery of gold in North Wales.

On the continent of Europe, leaving Russia for the moment out of the question, Hungary and Transylvania furnish from the sands of their rivers the chief supply of gold. The annual produce of Hungary is stated at 2,810 lbs. weight, and valued at 176,000*l.* The mines of Spain were anciently rich and valuable, but are now entirely neglected. This is the case also with the sands of the Danube, the Rhone, the Tagus, and many other European rivers, which possess gold in small quantities, but are rarely worth the expense of working. In the valley of the Rhine, indeed, between Basle and Mannheim, gold is found in little flakes accompanied with titaniferous iron. The gold spangles are exceedingly minute and thin, so that it takes from 1,100 to 1,400 of them to make a grain troy. They appear to be derived from the crystalline schists and other rocks of the High Alps.

The gold mines of Russia, which are the most considerable in the Old World, must come under the head of Asia, as they are situated to the east of the giant barrier formed by the Ural Mountains. During the century previous to 1841, the mines of Berezovsk in the neighbourhood of Ekaterinburg, yielded about 24,500 lbs. weight (avoidupois) of gold. In general the matrix consists of coarse gravel, but there are true auriferous veins enclosed in a band of rock, in which are many veins of quartz with gold disseminated. From these veins the valuable portions are extracted by vertical shafts and lateral galleries, and this is the only instance in the Russian territory where gold is extracted by the aid of subterranean workings. Much more generally the gold is found in fragments of rock which cover the earth to a considerable thickness, and is associated with other metals, as platinum and palladium. The quantity of gold obtained from the Russian mines has been greatly on the increase of late years. On the Asiatic side of the southern portion of the Ural mountains, sands of immense richness were discovered in 1842. Great success attended the search for gold throughout an extensive marshy plain near the site of former gold-mines, on the banks of the river Tachnou-Targanna. The whole valley had been searched except the part of it occupied by the buildings in which the washing operations were carried on. In the year named it was decided to remove these houses, whereupon not only were rich sands discovered, but under the corner of a building, at the depth of three yards, an enormous mass of gold was dug up, weighing upwards of 36 killogrammes, about 80 lbs. English. This mass was placed in the collections of the Corps des Mines at St. Petersburgh. A mass had been found in the same neighbourhood in 1836, weighing upwards of 22 lbs. English. It is not, however, usual to find large lumps of gold in the Ural districts, the fragments being commonly of small size, and only separated by washing, the yield seldom exceeding 36 grains of gold per ton-weight of soil, and never in ordinary cases more than 70. The sand of any river is considered worth washing for the gold it contains, provided it will yield 24 grs. per cwt., but the sand of many streams yields many times this proportion. In the eastern group of deposits, near the Altai Mountains, it is said that over a district as large as France, not only are considerable quantities of gold found mixed with sand and gravel on the surface, but even the rocks themselves, when pounded up, are found to yield a per-centage of that precious metal. The gold alluvia of Russia were known in the days of Pallas, and supposed to exist only near Ekaterinburg; in the reigns of Paul and Alexander they were found to extend, in a certain zone, to the north and south of that locality, and eventually half a million sterling was extracted from them annually. "The reign of the Emperor Nicholas," says Sir R. Murchison, "has been distinguished by the important discovery, that portions of the great *eastern* regions of Siberia are highly auriferous, viz. in the governments of Tomsk and Yeniseik, where low ridges, similarly constructed to those of the eastern flank of the Ural, and, like them, trending from north to south, appear as offsets from the great east and west chain of the Altai, which separates Siberia from China; and here it is curious to remark, that a very few years ago, this distant region did not afford a third part of the gold which the Ural produced, but by recent researches, an augmentation so rapid and extraordinary has taken place, that in 1843 the eastern Siberian tract yielded considerably upwards of two millions and a quarter sterling, raising the total gold produce of the Russian empire to near three millions sterling."

Other parts of Asia yield small supplies of gold, as the rivers of India, China, Sumatra, and Asia Minor; and now that the sagacity of the gold-seekers is fully on the alert, it is confidently to be expected that further discoveries will be made in the east.

Africa is at once pointed out by her "Gold Coast" as yielding the precious metal, yet the whole supply from that continent is not estimated at more than 5,000 lbs. weight annually. This includes the produce of the district between Darfur and Abyssinia, where the chief supply is found, the Mozambique coast opposite Madagascar, the Gold Coast, specially

so called, and the sands of the rivers Gambia, Senegal, and Niger.

America, long before the discovery of the Californian treasures, had become celebrated for gold mines, both in the north and south. The gold region of the United States extends along the eastern slope of the Appalachian chain of mountains, from the river Rappahannock in Virginia to the river Coosa, an affluent of the Alabama, in the state of that name. This immense stretch of country, bordering on the Blue Ridge, has many advantages over gold producing countries in general, owing to the mildness of the climate, the abundance of food, and the security which it offers to life and property. The most productive mines are in Virginia, North and South Carolina, and Georgia; but the gold region extends even to Canada, where the search for the precious metal is being carried on with some vigour at the present time. From Silliman's Journal we gain the following particulars of the mines of North America. "In Georgia, the richest mineral belt is in the talcose-slate, and granite formations, alternating with hornblende-slate, gneiss, and chlorite-slate: parallel mineral belts are found also near Augusta, but they cease with the termination of the primitive region. The most productive researches for gold have been made in the branch-streams or stream-mines, in the beds of rivers, rivulets, and ravines. In such cases little capital is needed, and few machines, except rockers, and the return is almost immediate and daily; from 5 to 10 dwts. per day for a single hand are not uncommon, and 120 have been obtained. In the loose deposits the gold is found in a bed of gravel, from 9 inches to 3 feet in thickness, and from 3 to 6 feet from the surface of the ground; it rests on slate, generally talcose, and is evidently the result of the destruction of a vein or veins crossing a watered ravine, or taking the same direction with it. The Burke rocker of North Carolina will wash a hundredweight (700 to 1,000 bushels of gravel) a-day, and the machine costs, when complete, but 25 dollars. Branch-mines have led to the discovery of many valuable vein-mines, for the miners, working until the gold seemed to fail, would come back and work into the banks or sides of the ravine, guided by the gold, and at last discover valuable beds of gold ore. Many instances of this kind have occurred in North Carolina and Virginia. The branch gold-mines of the United States are supposed to have yielded 6,000,000 dollars, most of which is worked up in jewellery, and not in coinage. The explorations for gold have not as yet been carried to a great depth, the greatest not exceeding 150 feet, and few of the shafts are over 100 feet; most do not exceed 20 or 30. These excavations are too shallow to afford satisfactory information respecting the gold, and the digging is often abandoned on the least unfavourable appearance, such as the narrowing of a vein, its dislocation, or its becoming shattered; for there is much appearance of disorganization in the veins and rocks. Pyritical ores constitute the mass of the ores in Columbia, Brazil, and the United States: above the depth of 100 feet they have been partially decomposed; the yellow ores have been converted into brown, red, and purple hydrates of iron, and a portion of the gold they contain having thus become uncovered, is accessible to amalgamation, while a large portion more is, or can be, developed by the assay by fire. Most of the gold is extracted by amalgamation, after stamping under water, and the residuum still contains gold. A committee from the Geological Society of Pennsylvania closely investigated the Rappahannock gold-mines in Virginia, situated on the river, about 10 miles from Fredericksburgh. The tract is about 230 yards wide, by an average length of 900 yards. The metalliferous veins consist of hard quartzose rock between walls of decomposed talcose slate. A portion of loose red soil, by washing two handsful of it, gave a considerable quantity of minute granular gold; and similar results were obtained by washings in other places. A principal auriferous quartz vein is from 2 feet 6 inches to 3 feet 6 inches wide; it stands vertically between walls of talcose slate. The auriferous quartz vein has been exposed to view for 627 feet, with a width of 30 inches, and it would appear that this is only the beginning. By a rough process of washing, amalgamation, and evaporation of the mercury, three and a half grains of gold were produced from 4 lbs. of the ore taken indiscriminately from all parts of the vein; and in another experiment 5 grains of gold were produced from 4 lbs. of pure milk-white quartz, which had no appearance or indication of containing any metal at all."

In South America gold is found on both sides of the great chain of mountains which runs parallel with the coast. The precious metal is gathered from the beds of streams which take their rise in those majestic heights. It is also found in a stratum of gravel and rounded pebbles at a great depth below the soil, and immediately incumbent on the solid rock. In former times, Brazil was the richest of American gold countries, and the precious metal is still found in more or less abundance, in nearly all the rivers which form the upper branches of the Francesco, Tocantius, Araguay, and Guaporè, but by far the largest quantity is yielded by the affluents of the Francesco. Yet it would appear that their golden sands begin to show signs of exhaustion. The work is, nevertheless, extensively and steadily carried on, and as the sands become exhausted, the mountains are the more diligently explored for the rich veins which often exist in their recesses. The greatest quantity of gold was obtained from Brazil between the years 1753 and 1763, and since that time it has always been on the decrease. This is not entirely owing to the impoverishment of the auriferous sands, but also owing to the want of capital to work the veins in the mountains on a regular system. British capital has at length been brought to bear on the undertaking, and the productive mines at Congo Soco, on the banks of the Rio das Velhas (a tributary of the Francesco) are the result. In addition to the Brazilian mines there are gold veins and washing for gold in Peru, and in other parts of South America; but all yield in importance to those we have named.

Gold (Au 100) has a characteristic yellow colour. Its specific gravity in its least dense state after fusion, is 19.2; by hammering and rolling it may be brought up to 19.3, or 19.4, or even, according to Berzelius, to 19.65. It fuses at a bright red, or a white heat, the temperature of which has been estimated at 2016° Fahr., and when in fusion, it is of a brilliant greenish colour: it contracts on cooling, and when the operation is slowly conducted, it forms short quadrangular pyramidal crystals. It is volatile at very high temperatures. A gold wire is reduced to vapour by the discharge of a powerful electric battery; and if the wire be placed just above the surface of a sheet of paper, the course of the discharge is marked by a broad dark purple stain, produced by the finely divided gold. If the paper be covered with silver leaf, the latter is gilt by the discharge. A globule of gold gives off abundant vapours when placed between the terminal charcoal points of a powerful voltaic battery. Gold is the most malleable of all the metals: it may be extended into leaves which do not exceed $\frac{1}{290000}$th of an inch in thickness, or a single grain may be extended over 56 square inches of surface, or be drawn out into a wire 500 feet long. The extensibility of gold is well illustrated by the process of gilding buttons, 144 of which are well gilt with 5 grains of gold, and in many cases only half that quantity is used. [See BUTTON.] Réaumur, by rolling out a fine silver-gilt wire, reduced the coating of gold to the twelve millionth of an inch in thickness, and the surface appeared to be perfect when viewed under the microscope. Gold, precipitated chemically, forms a brown powder, which under the burnisher readily assumes the metallic lustre and characteristic colour of malleable gold. This precipitate also admits of being aggregated or welded together by percussion; and if heated to redness before being hammered a second time, the metal becomes perfectly aggregated, without having been raised to its point of fusion. Gold does not combine directly with oxygen at any temperature. Sulphuric, nitric, and muriatic acids, do not act upon pure gold; neither does sulphur: nor is sulphuretted hydrogen decomposed by it. Chlorine and bromine attack it easily at ordinary temperatures; iodine exerts only a weak action upon it. Nitro-muriatic acid [see AQUA REGIA] dissolves gold with ease. It is also dissolved by muriatic acid, if a substance be added thereto capable of liberating its chlorine, such as peroxide of manganese, chromic acid, &c.

There is a suboxide of gold (Au_2O), and a peroxide or auric acid (Au_2O_3); also a subchloride (Au_2Cl) and a perchloride (Au_2Cl_3). This last is the most important compound of the metal, and is always produced when gold is dissolved in nitro-muriatic acid. When a solution of protosulphate of iron is added to perchloride of gold, the mixture acquires a dingy brown tinge, and if very dilute, a green or blue, as seen by strong transmitted light, an effect due to the presence of numerous small particles of gold in the metallic state: they quickly subside in the form of a brown powder, which, after having been washed in boiling water, digested in hot dilute muriatic acid, and again washed and dried, forms pure gold, in which state it is used for gilding porcelain. Perchloride of gold dissolves in alcohol and ether; polished steel dipped into the solution acquires a coat of gold; delicate cutting instruments are gilt in this way.

Chloride of gold added to a dilute solution of protochloride of tin, produces a brownish purple precipitate, known as the *purple of Cassius*:[1] it is used in enamel and porcelain painting, and also for tinging glass of a fine red colour: it retains its colour at a high red heat. When the tin predominates, it is of a violet colour, but with an excess of gold, it is more pink: these colours are communicated to enamel. The nature of this compound is not clearly understood, but it is supposed to be a combination of oxide of gold and sesquioxide of tin, in which the latter acts as an acid (or AuO, Su_2O_3). It is resolved by heat into a mixture of metallic gold and peroxide of tin.

The addition of liquid ammonia to chloride of gold gives rise to a yellowish brown precipitate, aurate of ammonia, or fulminating gold. It explodes at a moderate heat, by friction, or an electric shock. This compound has no application in the arts, nor, indeed, have the other compounds, except those which have been named in this article, and in the process of electro-gilding. [See ELECTRO METALLURGY.]

The addition of an inferior metal to gold tends only to degrade the noble metal; hence the alloys of gold are of very little importance in the arts, with the exception of those formed with silver and copper, which tend to increase the hardness and durability of gold. Silver confers a pale greenish colour on gold. English standard gold contains $\frac{1}{12}$th of alloy, which is now always copper.

Different shades of *colour* are given by the jeweller to ornaments of gold by exposing them to different chemical agents, which dissolve out a portion of the copper and silver alloy, while they have scarcely any action on the gold. By this means, the surface of the ornament is made to appear like pure gold; while below the surface the quantity of copper or of silver may be considerable. The French jewellers possess a number of recipes for giving colour to gold, the most common of which is a mixture of two parts nitre, one part sea-salt, and one of Roman alum. Of this mixture a quantity is taken about three times the weight of the jewels which are to be coloured, and a concentrated solution is made with boiling water. The jewels are kept in this solution at the boiling point from fifteen to twenty-five minutes, according to the shade required: they are then taken out, washed in water, and the operation is finished. The surface of the gold is dull, but perfectly uniform, but can be made lustrous by burnishing. They lose about $\frac{1}{16}$th of their weight by the operation. The methods adopted for recovering the metals from the solution, as also from the waste waters of the jeweller, are considered chemically by M. Berthier, in the *Annales de Chimie et de Physique* for 1835.

(1) It was discovered by Cassius of Leyden, in 1683.

GOLD BEATER'S SKIN. The preparation of animal membranes for various purposes in the useful arts is described in the article CAT-GUT, but we may here state, that after the membrane has been well cleaned in alkaline solutions, it is stretched out on a frame, with the mucous surface uppermost, and another membrane placed upon it in an opposite direction: the two clean surfaces unite readily and firmly. This compound membrane is next prepared with solutions of alum, isinglass, white of egg, &c., and is beaten between folds of paper to expel the grease, pressed and dried; but the routine of the operations cannot be stated very explicitly, as each manufacturer professes to have his own secret. A *mould* of skins, as it is called, is costly, but it will last several months without becoming too thin or weak for use. The leaves become in time unfit for work, but their flexibility is restored by placing them between leaves of white paper, and moistening them with vinegar or white wine; in this state they are loaded with weights, and left three or four hours. When sufficiently moist, they are put between leaves of parchment twelve inches square, and beaten for a whole day. They are then rubbed over with fine calcined gypsum, and are again fit for use. These skins are apt to get damp if neglected, and must be dried before being used.

In the Great Exhibition, Mr. Puckridge's Case (Class IV. No. 108) contained a variety of interesting illustrations of the manufacture of gold-beater's skin. 1. The cæcum of the ox, from which the skin is prepared. 2. Various stages of the skin in process of manufacture. 3. A gold-beater's *mould* as used in England and America, containing 850 leaves $5\frac{1}{8}$ inches square (each leaf being double), and $\frac{9}{16}$ths of an inch thick. To produce this requires the slaughter of 500 oxen. 4. The mould used in France and Belgium, consisting of 1,200 leaves, $5\frac{1}{4}$ inches square, to produce which requires the slaughter of 750 oxen.

GOLD BEATING. It was stated above that gold may be extended into leaves which do not exceed $\frac{1}{290000}$th of an inch in thickness. The proof of this remarkable tenuity is easy. For example, an ounce of gold is equal in bulk to a cube each of whose edges measures $\frac{5}{12}$ths of an inch, so that, placed upon the table, it would cover little more than $\frac{1}{6}$th of a square inch of its surface, and stand $\frac{5}{5}$ ths of an inch in height. The gold-beater hammers out this cube of gold until it covers 146 square feet. Now it can easily be calculated that to be thus extended from a surface of $\frac{5}{12}$ths of an inch square to one of 146 square feet, its thickness must be reduced from $\frac{5}{12}$ths of an inch to the 290,636th part of an inch.

The gold employed by the gold-beater should be pure; but various *colours* are obtained by alloys with silver, or with copper, in different proportions. The pure gold, or the alloy, is prepared for the gold-beater by melting in a crucible, and casting into flat oblong ingots, each about $\frac{3}{4}$ths of an inch wide, and weighing two ounces. Each ingot is then formed into a riband by passing it between two rollers of polished steel, and this laminating process is continued until the ingot is spread out to a surface of 960 square inches of the thickness of rather more than $\frac{1}{800}$th of an inch.

The riband of gold is annealed or softened in the fire, and cut up into pieces of the size of a square inch, and 150 of these are placed by means of wooden pliers between an equal number of leaves of vellum, each square of gold occupying the centre of each leaf of vellum. A parchment case, open at both ends, is drawn over this *tool*, or *kutch*, as the packet of vellum leaves is called, and this is enclosed in a second similar case, so as to cover the edges left exposed by the first case. This packet is then beaten with a sixteen-pound hammer upon a smooth block of marble, strongly supported from below, and surrounded on three sides by a raised ledge of oak; the front edge is open, and has a kind of leathern apron attached to it for catching fragments of gold that may escape in the subsequent operations. The elasticity of the packet causes the hammer to rebound, and thus lightens the labour of the operator, and enables him to apply his blows with regular effect; every now and then, in the interval between two blows, he turns the packet over to distribute the force equally, and he occasionally bends the packet to and fro to overcome any slight adhesion between the gold and the vellum; and at intervals he opens the packet to see that the work is satisfactory, and also to re-arrange the relative positions of the squares of gold, by placing those near the surface in the centre, and placing these near the surface. The beating is continued until the one-inch squares are spread out into four-inch squares. The packet is then opened, and each piece of gold is taken out, placed on a cushion, and cut into four pieces with a knife. This increases the 150 pieces to 600, and these are put between the leaves of another tool, called a *shoder*, made of gold-beater's skin. The packet is enclosed in parchment, and beaten with a twelve-pound hammer as before. The squares of gold are again spread out to nearly the area of the gold-beater's skin. The packet is again opened, the leaves of gold are again cut into fours, and each quarter is placed between two leaves of membrane as before. The gold is in this case divided by means of the smooth edge of a strip of cane, since it has a tendency to adhere to a steel knife. The squares of gold, now increased to 2,400, are separated into three parcels of 800 each; the squares of each parcel are again separated by gold-beater's skin, confined in the parchment cases, and beaten as before. These squares of gold-leaf expand for the third time nearly to the size of the leaves of membranes, and have at length attained the required degree of tenuity. The process of attenuation can be carried beyond this, but the gold is apt to tear, and the process requires great extra care. The three beatings and two quarterings expand the gold to an area about 190 times greater than it had in the form of a riband, and 100 square feet of it weigh only an ounce.

After the last beating, the thin leaves are taken up one at a time by means of a pair of long pincers, made of white wood, and being placed on a cushion, are blown out flat by the mouth, an operation re-

quiring considerable skill. Broken or injured leaves are rejected; but those which are perfect have the ragged edges cut off, which reduces their dimensions to about $3\frac{1}{4}$ inches square. Twenty-five of these leaves are placed between the folds of a paper book, the surfaces of which have been rubbed with red chalk, to prevent the gold from adhering, and in this form gold leaf is sold.

In the Great Exhibition gold-beating machines were exhibited from France and the United States. Mr. Bennett, of Clerkenwell, also exhibited what he termed *uniform leaf gold*, manufactured by steam machinery.

Silver and copper leaf are prepared in a somewhat similar manner to gold, but being less malleable, and also less valuable, they do not admit of being beaten out to nearly the same degree of tenuity as gold.

In a recent notice of gold beating[1] the operation is described from the commencement: $2\frac{1}{4}$ oz. of gold dust, mixed with $2\frac{1}{4}$ dwts. of silver and copper, were fused together to form what is called *deep gold*. The fused metal was cast in an ingot mould $1\frac{1}{2}$ inch long, by $\frac{3}{4}$ in. wide, and $\frac{3}{16}$ in. deep. The ingot was flattened into a riband $1\frac{1}{4}$ inch wide, 6 yards long, and about as thick as foolscap paper. This having been annealed was carefully marked out by compasses into 160 parts, which were cut out by shears into sections $1\frac{1}{4}$ in. square, each weighing between 6 and 7 grains, and worth 12*d.* or 14*d.* each. These 160 pieces being placed in a kutch, were beaten into leaves 4 inches square; these being cut up again made 640 pieces of the original size. In this state the leaf is called *dentist's gold*, and is used for stopping teeth. These 640 pieces were placed in the *shoder*, and beaten out to 5 inches square, which being cut up gave 2,560 pieces of the original size; on leaving this tool the leaves were equal to 10,240 pieces of the same size as the original 160. The leaves in this state were thin and transparent; they were cut into squares of $3\frac{3}{8}$ inches, 25 of which, in a book, sold for 15*d.*

GONIOMETER (from γωνία, an angle, and μέτρον, a measure), an instrument for measuring the angles at which the planes of crystals incline to each other.

GOVERNOR, or CENTRIFUGAL PENDULUM, see STEAM ENGINE.

GRADIENTS, see RAILWAY.

GRADUATION is the art of *dividing* mathematical, astronomical, and geodesical instruments. It is the most delicate, difficult, and important branch of the mathematical instrument maker's art, and few persons are gifted with sufficient accuracy of eye and precision of hand to excel in it. By its means an instrument, either by linear or angular measure, is made to determine the dimensions of objects, or their distance from each other. In a vast number of cases the value of the observation depends upon its accuracy; and this, again, upon the correctness of the graduation; and the importance of accurate observation will be at once appreciated from the fact, that a slight error in nautical astronomy may lead to the loss of a ship. In a circle of 3 feet radius, which is that of the mural circle at Greenwich, a minute of a degree is little more than the 100th of an inch, and this quantity, respecting latitude, is the measure of about a mile upon the surface of the earth; but in longitude, as derived from lunar and solar tables, the minute represents upon a mean no less than about 30 miles, while in some of the elements of astronomy, as obtained by observation, the disparity is very much greater.

The invention of the telescope soon led to that of instruments of observation, in which a correct system of graduation became more and more required. Some of the earlier astronomers who used the telescope graduated their own instruments; but before this, in most countries of Europe, clockmakers were the first to fabricate mathematical instruments. Thus the instruments invented by Hooke were made by Tompion, and he and Graham made instruments for the Royal Observatory at Greenwich, the establishment of which led to the production of superior instruments; and successive Astronomers Royal have, from time to time, encouraged the talents of superior artists. According to Smeaton,[2] the first person who cut accurate divisions on astronomical instruments, was Abram Sharp, assistant to Flamsteed. About the year 1689 he constructed and graduated for the Royal Observatory a mural sextant of $6\frac{1}{2}$ feet radius, which did good service to astronomy in the hands of Flamsteed. In the early part of the eighteenth century some instrument makers became celebrated in the art of dividing. Some of the works of Rowley are still extant, and are said to bear evident proofs of neatness and accuracy. A little later than Rowley the elder Sisson constructed and graduated large instruments with success, such as the 8-feet mural, and several large zenith sectors of Graham. About 1727 Bird, a rustic lad of Bishop-Auckland, observing the unequal divisions and coarse engraving of a clock-dial plate, determined to execute one for himself. The success of the attempt attracted notice, and he was enabled, a few years afterwards, to come to London, where he served a short apprenticeship with the elder Sisson, and became acquainted with Graham, from whom he acquired much valuable information. In 1745 he was in business for himself, and he and the younger Sisson were rivals for fame. It is said that the latter was as superior in ingenuity as the former was accurate in execution and sound in judgment. In 1767, at the request of the Commissioners of the Board of Longitude, Bird published his method of dividing, and was rewarded with 500*l.*, besides 60*l.* for his plates, he having agreed to instruct an appren-

(1) Contained in No. 8 of *The Leisure Hour*, published by the Religious Tract Society.

(2) The celebrated Smeaton began life as a mathematical instrument maker, and his paper in the *Philosophical Transactions* for 1786 contains a variety of details, which, probably, no one else could have written. Its title is: "Observations on the Gradation of Astronomical Instruments: with an Explanation of the Method invented by the late Mr. Henry Hindley, of York, Clockmaker, to divide Circles into any given number of Parts. By Mr. John Smeaton, F.R.S. Communicated by Henry Cavendish, Esq. F.R.S. & S.A. Read November 17, 1785."

tice of seven years in the art of constructing and dividing astronomical instruments. About 1740 Henry Hindley, of York, was the first to construct an *engine* for graduating instruments, and which also served to cut the teeth in clock-wheels. In 1768 the Duc de Chaulnes published at Paris his "Nouvelle Méthode pour diviser les Instrumens de Mathématique et d'Astronomie;" also, "Description d'un Microscope et de différens Micromètres destinés à mesurer des parties circulaires ou droites avec la plus grande précision." This method has been considered as the basis of Ramsden's method of dividing a large circle. The last named celebrated artist had the great merit of rendering small instruments almost as accurate as the large ones had previously been, and the graduation of his larger works was superior to any that had been executed. About the year 1766 he constructed a dividing engine, which, although it fell short of his expectations, exceeded in accuracy the best dividing plate. It answered well enough for dividing common instruments, but was not sufficiently accurate for those used in finding the longitude at sea. Ramsden's second effort was much more successful. A sextant, divided by the new engine, was carefully examined by Bird, and pronounced by him to be fit for every purpose of nautical astronomy. Ramsden's engine was well suited to the time in which it appeared,—a time when the improvements in nautical astronomy, and the extension of our commerce, created a great demand for reflecting instruments, which never could have been supplied if it had been necessary to divide them by hand. In 1777, at the request of the Commissioners of the Board of Longitude, Ramsden published on oath an account of his engine, for which he received a reward of 300*l.*, and a further sum of 315*l.* on condition of making over his engine to the public, and engaging, so long as the engine remained in his possession, to divide sextants at 6*s.*, and octants at 3*s.* each, for other mathematical instrument makers.[1] The instrument makers, however, complained that Ramsden kept their work too long in hand, and that his assistants were very careless. Such complaints as these would be likely to stimulate ingenious men to copy Ramsden's engine now that it was public property. The first to do so was Mr. John Troughton, who, after labouring during three years, with much self-denial and straitened pecuniary means, completed, in 1778, a graduating engine, which soon became the successful rival of Ramsden's; and although Troughton charged a higher price than Ramsden for graduating for the instrument makers, yet his engine was soon in full employment, and he was accustomed to declare, in after years, that, by the care and industry of himself and of his younger brother, he was soon as well remunerated by the trade as Ramsden had been by public rewards. About 1788 Mr. John Stancliffe completed his dividing engine; he had been apprenticed to Hindley, of York, and was for many years foreman to Ramsden, whom he is said to have greatly assisted in the construction of his engine. Stancliffe had been chiefly occupied in the graduation of sextants, which, after leaving his hands, were long and deservedly esteemed. After this, Ramsden's engine was copied many times. Troughton continued during many years to practise graduation with success; and he was worthily succeeded by his younger brother, Edward, who was destined to shed lustre on his profession. He conceived and realized an improved method of graduation, which, after having tested by several years of practice, he at length submitted to the Royal Society of London, and was rewarded by that distinguished body with the Copley medal. His memoir, which is inserted in the Philosophical Transactions for 1809, will be noticed more fully hereafter; but we may here quote his own account of the circumstances which first led him to become dissatisfied with the old methods of graduation. He says: "With as steady a hand and as good an eye as young men generally have, I was much disappointed at finding that, after having made two points, neat and small to my liking, I could not bisect the distance between them without enlarging, displacing, or deforming them with the points of the compasses. This circumstance gave me an early dislike to the tools then in use, and occasioned me the more uneasiness, as I foresaw that it was an evil which no practice, care, nor habit could entirely cure; beam-compasses, spring-dividers, and a scale of equal parts, in short, appeared to me little better than so many sources of mischief. . . . . Of the different branches of our art, that of turning alone seemed to me to border on perfection. It occurred to me, that if I could by any means apply the principle of turning to the art of dividing instruments, the tools liable to objection might be dispensed with. The means of doing this was first suggested by seeing the action of the perambulator, or measuring-wheel; the surface of the earth presenting itself as the edge of the instrument to be divided, and the wheel of the perambulator as a narrow roller acting on that edge; and hence arose an idea that some easy contrivance might be devised for marking off the revolutions and parts of the roller upon the instrument."

While Edward Troughton was occupying the attention of the Royal Society with his method of graduation, the Hon. Henry Cavendish also submitted a new method of using the beam-compasses, with a view of avoiding the difficulty of pointing the exact middle of a small space between the two scratches, and of using that point again without altering its conical figure. About the same time, Professor Lax, of Cambridge, communicated to the Royal Society a paper on the art of graduation, which, however, greatly resembled the Duc de Chaulnes' method of dividing a circle. In 1810 Mr. James Allan, a workman, received the gold medal of the Society of Arts for a new, and what he terms a "self-correcting" method of equalizing the teeth on

(1) Ramsden also invented a machine for dividing straight lines, in which he used a screw as his original. The value of this machine is not equal to the former, since a long screw cannot be made so accurate as a scale divided by bisections. Mr. Bryan Donkin has contrived a machine in which a screw is the scale, but its errors are corrected by other mechanism. By means of this machine scales have been divided and screws cut with great accuracy. A short account of this machine is given in the second volume of Holtzapffel's "Mechanical Manipulation." We shall have to notice it in the Article Screw.

the edge of the engine-plate used for dividing sextants. About the year 1830 Mr. Andrew Ross was rewarded by the Society of Arts for an improved method of dividing, and also for a new circular dividing-engine. In 1843 Mr. Simms, of the firm of Troughton and Simms, applied self-acting apparatus to Edward Troughton's circular dividing-engine.

Dividing-engines have been constructed by Reichenbach, and others, in Germany, and by Gambey, Froment, and others, in France.

Much of the German division is excellent, and of late years Froment's division has excited great admiration. His method is not known in this country, but we believe it is done by a self-acting engine, which is moved by the electro-magnetic machine described at p. 577 of this volume.

The art of graduation is commonly divided into three sections, viz.: 1. Common Graduation; 2. Engine Graduation; 3. Original Graduation.

1. *Common graduation* is the method of taking copies from a pattern which has been already laid down by original graduation; but, as generally practised, it consists of taking copies of a copy. It also includes those cases of original graduation where the usual patterns do not apply, and where the utmost possible degree of accuracy is not required.

The apparatus used with certain tools for common graduation, consists of a *dividing-plate*, which is either a complete disc, or a broad rim connected with the centre by radial arms, and made inflexible by circular rings or edge bars beneath. It may vary from 14 to 30 inches in diameter. The extreme border is divided into degrees and quarters, and just within this is another circle, divided into degrees and thirds. Within are usually engraved such numbers as are required for the dial of the perambulator; Gunter's line of numbers arranged in a circle, and other logarithmic lines. Also tangents in hundredth parts of the radius, and the difference of the hypothenuse and base as applied to the theodolite; also the equation of time for dialling, the points of the compass, &c. In the centre of the plate is a circular hole, made truly perpendicular to the surface, into which is nicely fitted a pin or arbor, which also fits the centre hole in the circle or arc to be divided, and is the principal connexion between it and the dividing-plate while the work is being done. In Fig. 1098 the dividing-plate is shown with a compass ring attached, in process of graduation; this ring is prevented from turning round by means of a couple of holdfasts, two being used, since it is necessary to remove one of them when its position obstructs the work. An index of tempered steel, with a very straight edge, is attached at one end A to a plate of brass, furnished with an angular notch exactly in a line with the straight edge, which notch receiving the arbor of the plate directs the straight edge to the centre. The length of the index is equal to the radius of the plate. At, and below the exterior end, is fixed a secondary index B, reaching as far inward as the lines of the plate extend, its edge being also directed to the centre, but usually placed a little to the right of the other edge, as in the figure. By an arrangement of nuts and screws, the distance of the two parts can be adjusted according to the thickness of the work, so that the secondary index may be flat upon the work. For instruments which are required to be divided on feather edges, such as protractors, a flexible index is sometimes used, so that the pressure of the hand may bring it in contact with the inclining plane; but a secondary index is preferable, if it allow of its position being adjusted to the plane which is to receive the divisions.

The dividing-knife, Fig. 1099, consists of a blade of good steel and a handle of beech-wood. The cutting edge should be quite straight, in a line with the handle, and of the same thickness as the intended divisions. The edge must not be sharp, but rounding, so as to

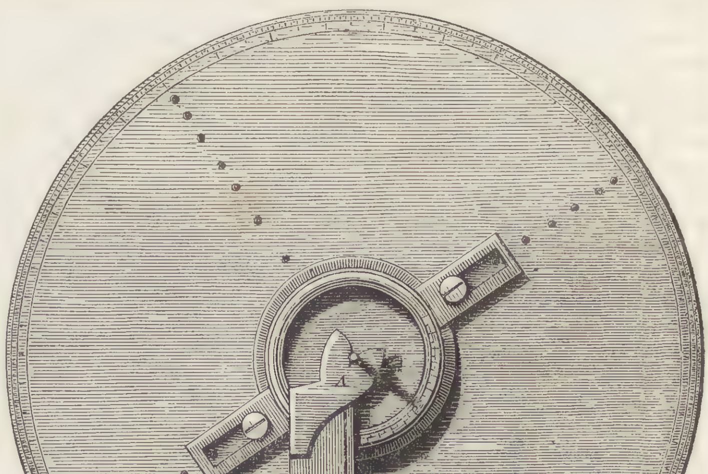


Fig. 1098. DIVIDING PLATE, WITH A COMPASS RING IN PROCESS OF GRADUATION.

present to the surface which is to be divided a small semicircle, whose radius is equal to half the breadth of the line which it is to make. The back of the blade is about $\frac{1}{15}$ inch thick. The left side should be flat, but

the opposite side chamfered in a faint curve from back to edge. The extreme end of the blade makes with

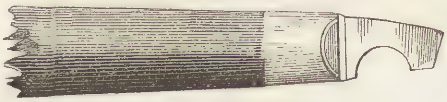


Fig. 1099.

the line of the edge an angle of about 70°. A small chamfer on the side to the right, broad at the back, but vanishing at the edge, reduces the end to an equal thickness. A semicircular recess is made in the edge of the blade near the handle, which affords a relief when the tool is sharpened, and is useful for receiving the inner side of the end of the middle finger. For the further accommodation of the finger, a part of the ferrule of the handle is cut away, as shown in the figure. The curved back of the blade enables the operator to see his work better. The knife is held very much like a pen, but the handle must be quite home between the thumb and forefinger, which, being placed upon the ferrule directly over the back, is, by its pressure, the chief agent in giving depth to the divisions, the thumb and middle finger acting as supporters, while the other two fingers, as in writing, prop the hand. The knife is held at an angle of about 45° with the plane to be divided, and is used with the flat side in contact with the index of the dividing-plate. The action of this knife is the reverse of the graver, which is *pushed* outwards, and cuts away a fibre in the line of its course, leaving the rest of the metal undisturbed; whereas the knife is *drawn* inwards, and without producing chips, cuts a furrow, while the metal displaced rises in a bur on each side, which is afterwards removed by rubbing with willow charcoal and water.

Before making the divisions, the circular lines, which limit the length of the strokes, are marked out by means of a beam-compass, and made of sufficient breadth and depth by the dividing-knife. The compass ring to be graduated is attached to the dividing-plate, its zero, or north point, being placed so that the index when set to it may also agree with the zero of the plate. The operator then drops the point of the dividing-knife into the line on the plate, and pressing the index to prevent its moving, cuts the corresponding stroke upon the ring. The index is now drawn forwards something more than the value of a division, and the knife being fixed in a second line, it is then pushed back into contact with it, and a second stroke cut as before. In this way he proceeds from right to left until the circle is completed. In dividing upon metals this work is laborious for the hands, and there must be frequent intervals of rest, during which the work is examined with a lens. In dividing upon ivory and wood, the work is so light that an operator will keep pace with a skilful seamstress, a division for a stitch, for any length of time.

Common dividing, as applied to straight lines, is similar to circular dividing. The pattern, of course, is straight, and the scale on which the copy is to be laid is placed beside it; instead of the index above described, the lines are ruled with what is called a *dividing square;* this consists of a straight-edge made of thin tempered steel, with a shoulder at right angles, like a carpenter's square. It is made to slide along the original, stopping at each division, when a corresponding stroke is cut by the dividing-knife on the copy.

When box, or other wood, has been divided upon, the bur is first well rubbed off the divisions, and the whole surface polished with a dry rush; the surface is next burnished by rubbing it hard both ways, in the direction of the grain of the wood, with a clean piece of old hat, whereby an agreeable gloss is produced. The divisions are blackened by a mixture of powdered charcoal and linseed oil, laid on quickly, rubbed hard, and cleared away. This finishes the process. In ivory the divisions are first filled in with a composition of lamp-black and hard tallow, or bees'-wax and olive-oil; when this has been hard rubbed into the strokes, the whole surface is well rushed, and then polished with chalk and water, laid upon a linen rag. In finishing brass, after the bur has been taken off with charcoal and water, the surface should be finished off with wet blue-stone, which is a very soft slate. Divided gold and silver are best finished with charcoal; but all the metals are improved by being rubbed with the hand after a little oil has been applied.

The *beam-compasses* consist of a beam, A A, Fig. 1100, of any length required, generally made of well-seasoned mahogany. Upon its face is inlaid throughout its

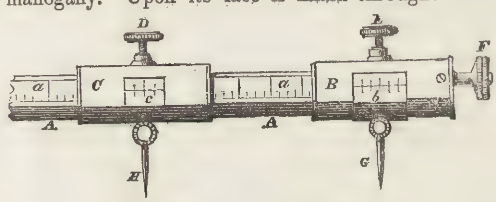


Fig. 1100. BEAM-COMPASSES.

length a slip of holly or box, *a a*, upon which are engraved the divisions or scale. Two brass boxes, B C, are adapted to the beam, of which boxes the latter may be moved by sliding to any part of its length, and is fixed in position by tightening the clamp screw D. The two points G H are attached to the boxes, and these may be made to have any extent of opening by sliding the box C along the beam, the other box, B, being firmly fixed at one extremity. The nice adjustment of the points G H is attained by means of the two verniers [1] *b, c,* fixed at the side of an opening in the brass boxes to which they are attached, and afford the means of minutely subdividing the principal divisions *a a* on the beam, which appear through these openings. E is a clamp screw for a similar purpose to the screw D, viz. to fix the box B, and prevent motion in its point after adjustment to position. F is a slow motion screw, by which the point G may be moved a minute quantity for perfecting the setting of the instrument after having been set as nearly as possible by hand alone.

For some descriptions of dividing, the compasses

(1) The principle of the Vernier is explained in Article BAROMETER, page 103.

called *spring dividers*, Fig. 1101, are useful. They consist of a circular steel bow and two legs, all in one piece: the bow allows a motion of the points from the distance of about an inch, or 2 inches, to their contact. The points may be brought near together

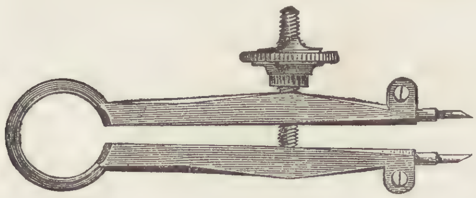


Fig. 1101. SPRING-DIVIDERS.

by means of an adjusting screw attached to one of the legs by a pin passing through it, and upon which it turns as in a centre, the elasticity of the spring exerting a pressure against the screw, (or rather against a sharp angle attached to the screw,) and thus keeping the points at the distance to which they are set. The legs are bored to receive the cylinders or points, which are ground to the requisite fineness and brought very near the inner extremity of the diameter in order to measure the shortest possible distance; but at the point they are made round, and in every direction the sides must make equal angles with the perpendicular, otherwise a distance set off with them would be altered by pressure. In using this instrument the forefinger is pressed upon the bow, the thumb and middle finger keeping it upright, while the other fingers prop the hand; but where a distance is to be set off many times in succession, the dividers are to be twirled round in the same direction, making a dot at every half turn. For accurate bisection of a distance, the instrument must be held by the leg near the point, which is lodged in one extremity, while with the other a faint arc is described; the same thing being done from the other end of the distance, the middle point is secured by making a dot with a fine conical pointril. In using the dividers a magnifying glass held in the left hand must always be employed.

In dividing a common thermometer, several points, 12 or 15 degrees apart, are marked off in accordance with a standard instrument; these, which are always unequal, are filled up with equal parts. Suppose the distance from one mark to the next is 15°; instead of first dividing the space into 3 or 5, the operator guesses, or estimates the distance of 1°, and running the divider over the space almost as quickly as he can count its steps, he ascertains how much he has erred; a second or third trial is sure to give him the proper distance. The dots in these trials, two of which should never be in the same line, are scarcely to be recognised by the lens, and he requires the last set only, so that by repeating the steps with greater pressure he may make the dots sufficiently large to receive the point of the dividing knife.

2. *Engine graduation.* — Ramsden's engine has formed the basis of the subsequent improved instruments, which we are about to describe; it will not therefore be necessary to give more than a general idea of its principle, which is as follows:—A horizontal circle 4 feet in diameter is made to turn upon a vertical axis: the outer edge of this circle is *ratched* or notched by an endless screw, one revolution of which carries the circle round 10′: the pressure of the foot upon a treadle turns the screw forward, and by a series of ingenious contrivances the operator can turn the screw through any portion of its revolution at each descent of the treadle, and the position of the parts is restored when the foot is taken off, without allowing any return motion to the screw. The circle to be divided is fixed upon the dividing engine, and made concentric with it, and a division is cut after each pressure of the foot.

Mr. Edward Troughton's dividing engine, which was completed in 1793, will be understood from the following figures and description.[1] Fig. 1102 is a plan, and Fig. 1103 an elevation of the engine. It is mounted upon a strong frame of wood, the upper part of which serves as a box to preserve it, and which at certain places opens for use. This stand serves to support the machine at a convenient height, and the only portion of it represented in the figures is the platform E E. The lowest part of the engine is a heavy tripod of cast brass; two of its branches are denoted by A A in the plan: the third is covered by the work above. In Fig. 1103, the tripod is also represented by A A, below which are three finger screws B B, that support it on the platform and serve the purpose of levelling the engine. They work in the tripod with their heads downwards, and are placed in the broad part where the two branches meet. At about 2 inches from the centre of the tripod, and at equal distances from each other, are 3 conical tubes C C, extending downwards nearly 3 feet; the third is concealed behind the axis of the engine plate. They are connected at the lower ends by a strong piece of brass F, which, together with the centre of the tripod, forms a frame wherein the axis revolves. The engine-plate G was cast in one piece, except the circular limb. The form of the 12 radii is seen in Fig. 1103: they are connected by a central part, equal in thickness to their greatest depth; but the broad circular centre piece, as well as the circular ring, are not thicker than the limb. The latter is 3 inches broad and ½ inch thick, and is formed of one piece of fine plate brass without soldering. It is rabbeted upon the extremities of the radii, so as to bring its upper surface into the same plane with them, and made permanently fast with rivets. The axis of the plate D is a strong conical tube 4 inches in diameter at the upper end, and half as much below. Its length is determined by the 3 cones of the tripod. At the upper end it is firmly fixed to the centre of the plate; the lower end terminates in an obtuse point of steel. At the upper end of the axis, a steel arbor was passed through the plate from below, 2 inches above its surface: upon these 2 points when revolving in

(1) Mr. Ed. Troughton described his own engine in the *Edinburgh Cyclopædia*, article GRADUATION, from which our description is abridged. We are also indebted to this article for much valuable information in the other sections of this notice.

the lathe, the surface of the plate was generated and its outer edge made perfectly circular. The teeth in the limb were cut by a screw having 20 threads in an inch, and as it was intended that by one of its revolutions it should carry the plate through an angle of 10′, it followed that the circumference of the plate should be 108 inches. From the measure of the screw, therefore, the dimension of the exterior border of the plate was derived first by computation nearly, and afterwards by trial with the screw itself.

A strong collar of bell-metal had been soldered upon the axis and made concentric with it when the limb was turned, the position of this collar coinciding in height with the body of the tripod. The centre of the tripod is hollow, to allow the collar to pass through, but does not form a socket for it to work in. Instead of that, two narrow pieces of steel are fixed vertically at an angle of 120° with each other. Against these the collar is pressed by a steel spring planted at 120° distance from them. In this triangular bearing the axis is supported at top, while the piece F receives the point at the lower end, and supports the whole weight. To the front branch of the tripod is screwed a strong plate of brass, as shown in the plan, extending inwards half-way to the centre and outwards somewhat beyond the border of the wheel. Its breadth is rather more than the length of the screw arbor. Above this and in contact with it, is a similar plate, to the under side of which are screwed 3 oblong pieces, the thickness of which is equal to that of the lower plate. One of these at the middle of the inner end of the plate, and the other two at the outer end near the edges, are received by slits cut in the lower plate, and which are about $\frac{1}{8}$ in. longer than the pieces, and allow a motion of the upper plate in the direction of the radius, equal to that quantity, but afford it no lateral play. The dividing screw is fastened to the upper plate, and partakes of its motion, in order that, when required, the threads of the screw may be disengaged from the teeth of the limb. Two pieces H, connecting the screw with the upper plate, extend towards the centre as far as the plate, and form edge bars to strengthen it. In Fig. 1105 the shape of these pieces is best shown, and the mode in which they are brought from below for placing the screw even with the edge of the wheel, and also how the screw arbor is centered in them. The arbor of the screw is cylindrical, and a portion of each end forms a cylinder of smaller diameter. The shoulders which near each end of the arbor limit these parts, prevent lateral play in the pieces last described; for the smaller parts work freely in the holes of those pieces, the shoulders being in contact with their inner edges.

The engine was now ready to receive the original graduation of its limb, and this was done according to the principle explained in the third section. It may, however, contribute to the completeness of this part of our subject to select a few particulars from Mr. E. Troughton's account of the actual process on the engine under description. In the first place, a roller was placed horizontally in a frame attached to the tripod so as to have free and steady motion round its own axis; and was so adjusted as to be carried exactly 16 times round while the engine-plate made one revolution. This roller was itself, near the edge upon its upper surface, divided into 16 parts. Upon turning the plate round, these 16 divisions 16 times told = 256, came in succession to the wire of a fixed microscope, and were by a proper apparatus transferred to the surface of the plate, in fine dots, at a sufficient distance within the edge to prevent their being disturbed by making the teeth. To accomplish the next step an index was made to revolve upon the arbor of the plate; it was composed of two branches equal in length to the radius of the circle of dots, each of which carried at its extremity a microscope with a micrometer: these had a range of angular motion respecting each other from a right line to a very small angle. By this index and these microscopes the 256 fine dots were examined by a certain bisectional process, from which their individual errors were investigated by computation and formed into a table. By the help of the table of errors, the future work of racking the limb was prosecuted with as much certainty as could have been done had the original divisions been inserted without error. As the value of a tooth of the limb was to be 10′, the whole number of teeth would be 2,160; now $\frac{2160}{256}=8\frac{7}{16}$; and just so many revolutions and parts of the dividing screw will be commensurate with a mean space from dot to dot = an angle of 1° 24′ 22″.5. In order, therefore, that a comparison between the plate and the screw might be made at every original dot, it was necessary to provide means for ascertaining the position of the former at every 16th part of a revolution. To this end a micrometer head, as large as could be admitted, divided into 16 equal parts, was fixed upon the left end of the screw arbor, and contiguous to this was placed a fixed index bearing a fiducial line. Now, as it was impossible to lay down these 256 dots without some errors, it was necessary next to determine their true places from their apparent ones. A lower subdivision of the micrometer head, therefore, became necessary, and each of the 16 spaces was divided into 10 by actual division.

The 256 dots having been transferred to the plate, the roller was removed, as also the double index and microscopes from the central arbor, when the position of those dots had been ascertained. The dividing screw was now placed in its frame; and a micrometer with a movable wire fixed to the tripod for viewing the primitive dots, and a winch for turning the screw attached to its arbor on the right; this change of parts being effected, the screw with its frame having free motion in the line of radius, and capable of being, by the force of a spring, pressed into contact with the edge of the plate, or by a screw drawn backwards at pleasure: the plate itself having free motion round its axis, the important operation of forming the teeth or racking the circle was commenced.

In order to prevent mistakes by beginning an interval at a wrong 16th of the head, which by making false marks would occasion much trouble,

those parts were numbered 1, 2, 3 . . . 16 in the order of turning the screw forwards. Corresponding numbers were marked in ink upon the plate opposite to the dots, the order of which, from right to left, was 0, 7, 14, 5, 12, 3, 10, 1, 8, 15, 6, 13, 4, 11, 2, 9, which, repeated 16 times, completed the circle. This allowed the work to be done with confidence, for, in beginning any interval, it was only required that the number upon the head should be that which distinguished the dot under the wire of the microscope. In the table of errors those dots which were too forward were marked with the sign —, and those that were too backward +, since a + position of the screw will effect a correction of a — error of the dot, and the contrary. The *zero*, or first dot, being without error, is, by turning the plate round, to be brought exactly under the wire of the microscope, and the division of the head marked O made to coincide exactly with the fiducial line. The spring is now allowed to press up the screw into contact with the edge of the plate, and then, by means of the winch, the screw is to be turned through $8\frac{7}{16}$ revolutions, which will make impressions upon the edge of the plate and bring up another dot to the wire of the microscope. The screw must now be released, and the plate turned backwards so as to bring that dot to the wire which precedes the one that the former interval began from, which dot is marked 9, and the division of the head marked 9 must be brought to the fiducial line, but not exactly; for in this, as well as in every future interval, the tabular error of the dot must be allowed for according to the subdivisions of the head; the screw being again pressed up and turned with the winch, this interval will also be indented. In thus proceeding in a retrograde course from one interval to another, until the whole circle has been gone over, a slight impression of the screw is made at each of the 2,160 revolutions. The marks thus made are laid on, as it were, in patches, the beginnings of which are agreeable to the original corrected dots, but at every other point they are subject to the error of mismeasurement of the screw as well as to that of its uncertain action. The backward process in making the first impression was to prevent accumulated error, which must have arisen had the screw been turned forwards through successive intervals; but as the impressions already made were sufficiently deep for the screw in its future action to follow them, and by its own equalizing action to produce agreement between the beginning of one interval and the end of another, it was necessary to pursue that process. Thus far the threads of the screw had not been made to cut, but merely to indent the edge, the metal on each side of every indentation rising in a bur; but 4 or 5 of the middle threads had already been worn into action. In order to rack from these slight indentations to the full tooth, it was necessary that the screw should cut like a saw; for which purpose the spiral notches, which in opposite directions are shown in the figures crossing the threads of the screw, were made with a sharp-edged file, and in order to preserve sharpness through long-continued action, these notches were, from time to time, filed deeper and broader. The operation was a tedious one, and occupied nearly a month. The chief difficulty arose from the circumstance, that the threads of the notched screw cut sharper with one edge than with the other, and consequently the indentations gained or lost upon the original divisions. By frequently sharpening the screw opposite various parts of the limb, the error arising from this source was sometimes +, and sometimes —, and that to the amount of 7″ or 8″ in some parts of the circle. These errors were corrected from time to time, as they were found to exist, by pressing the wheel forwards or backwards, so as to force the screw in its revolution to remove more metal on one side of the indentation than on the other. This Mr. Troughton thinks a sufficient answer to those who would propose a self-correcting method of racking an engine. In former engines the notches of the screw were cut parallel to the axis, which caused an irregular jerking motion in consequence of the whole length of each cut coming into action at once, thereby cutting up the screw, and rendering a duplicate necessary. In the present engine this inconvenience was avoided by making the notches in spirals which, crossing each other at equal angles, gave in one set the preceding edge, and in the other the following edge, the most advantageous cutting angle. Besides this, a revolving pressure was sufficient to cause the notches to rake off every impurity from the teeth of the wheel and keep them perfectly clean.

We now return from this long description of one of the most delicate and difficult of mechanical operations, to complete the description of the engine. Fig. 1106 shows, in perspective, the apparatus for carrying the wheel forwards by the screw, the connexion between the screw and the foot, and the method of stopping at every division. The chief parts of this apparatus are shown in all the figures; but the method of supporting it on the platform of the stand, by the block I, is seen only in Fig. 1103. The principal piece is a cock, J, the horizontal part of which has two branches, one shown in the figure, between which the strings pass to the T treadle, Fig. 1103. The vertical part supports a steel cylinder, which, when the screw is in action, forms a right line with its arbor; but there is left between their ends a space of about half an inch: this affords means for changing the ratchet wheels which are placed upon the screw arbor, and move round or stop with it. A barrel, about 2 inches long and $1\frac{1}{4}$ diameter, is fitted upon the cylinder, but so as to be turned round and moved upon it with perfect freedom from end to end. The middle part of the barrel is formed into a spiral worm, or screw, the groove of which receives a cord or cat-gut of $\frac{1}{16}$ inch in diameter. There is a slight frame dove-tailed upon the horizontal branches of the cock, shown in front of Fig. 1104, which has steady and free motion in the direction of the cylinder; to each side of this frame is attached a pallet, one of which enters in front, and the other behind, into the spiral of the barrel, by which means,

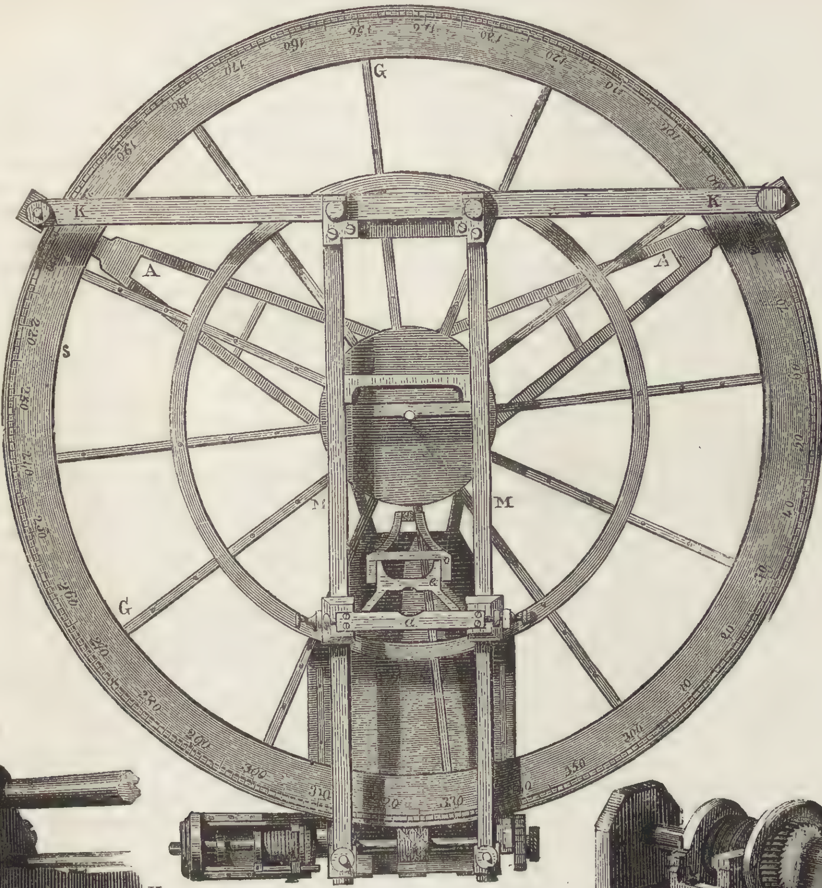


Fig. 1102. PLAN.

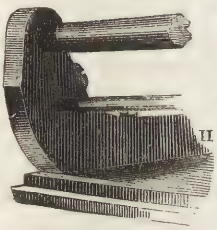


Fig. 1105.

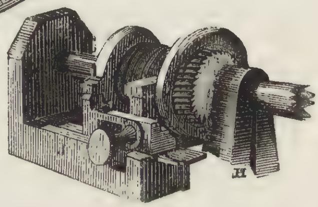


Fig. 1104.

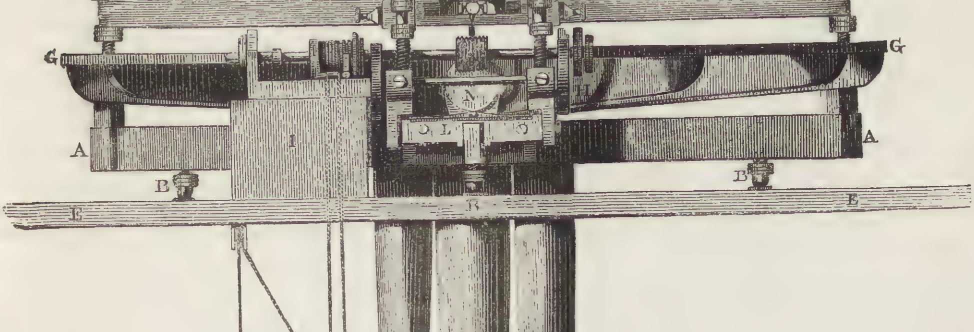


Fig. 1103 ELEVATION OF TROUGHTON'S DIVIDING ENGINE.

when the latter is turned round, rectilinear motion is given to the frame. The barrel to the right is large and excavated, so as to admit the ratchet-wheel, which latter is driven by a catch and spring planted in the edge of the cavity in the former. The end of the barrel to the left is embraced by a ring, which is capable of being turned round or set fast at pleasure. A stopping-piece is fastened to the frame by a finger-screw, and by means of a slit, through which the screw passes from the ring of the barrel, varied through a considerable extent. The elevated part of the stopping-piece resembles an anvil, and the hither side of the ring of the barrel, a hammer: the contact of these determines the point from which divisions begin: each division is terminated by similar means: an anvil is found in the elevated part of the frame

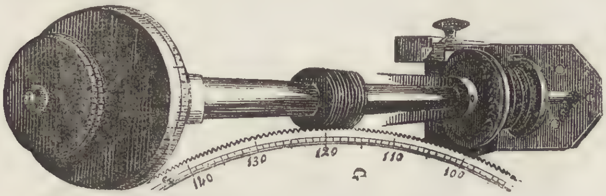


Fig. 1106. PART OF ENGINE PLATE, WITH THE MILLED HEAD AND DIVIDED MICROMETER.

behind, and a hammer in a screw-head projecting from the enlarged end of the barrel: a string, occupying 4 or 5 turns of the groove of the barrel, is attached at one end to a treadle near the floor, and at the other, after passing over two pulleys, to a weight behind. When the treadle is pressed down with the foot, the hammer in front is lifted off its anvil; and as the barrel is carried round, the frame is moved forwards by the pallets, so that in the second turn they pass clear of each other, and the motion is continued until the anvil behind is struck by the other hammer: during this time the catch, by the pressure of its spring, has hold of the perpendicular side of a tooth of the ratchet wheel, carries the screw round along with it, and moves also the engine-plate through the proper angle. On gradually withdrawing the pressure of the foot from the treadle so as to let the weight prevail, the barrel will be brought round in a contrary direction: the hammer and anvil on the further side leave and pass each other, and then those on this side pass and meet as at first, ready for a second tread. During the time that the barrel runs backwards the screw and engine-plate stand still; for the sloping sides of the ratchet-wheel allow the catch to escape freely over them. According to the arrangement in Fig. 1104, a tread gives only 2 revolutions of the screw, but the number may be varied at pleasure as far as 6; for let the anvil in front be placed by its finger-screw so much to the right as will allow the hammer to escape it, the weight will then draw the barrel back through another revolution and the parts will meet again. Parts of a revolution are obtained with equal ease. As the ring of the barrel, to which is attached the hammer in front, may be turned round and fixed at pleasure, it is evident that if the hammer were brought down so as to meet the anvil sooner, the tread would be shortened; and if shifted the contrary way it would be lengthened. Thus, by changing the position of the anvil, the number of complete revolutions can be varied; and as parts of a revolution are obtained by shifting the hammer, the angular value of a tread may be varied from 6 revolutions of the screw down to a single tooth of the ratchet-wheel. The most useful number for the teeth in this wheel is 120, for it answers to the division of the vernier that gives 5″ of the usual degree, or 10″ in instruments of reflexion, as well as to many others. For other purposes ratchet-wheels, of 80, 100, &c. teeth, may be substituted.

On the end of the screw-arbor to the left, Fig. 1106, is attached a milled head and divided micrometer; the latter, like the ratchet-wheel, changeable at pleasure, and carrying the same number of divisions that the wheel does teeth; the micrometer turns round with the screw, and a cock fixed to the frame, bearing a fiducial line, serves as an index for counting the divisions. By the help of this the stopping apparatus can be set to any part of the revolution of a screw without the trouble of a second trial; and by it, in case of a false tread, or other accident, the parts can be again adjusted.

The frame and apparatus for cutting the divisions, and their connexion with the engine, have now to be described. Upon the two remote branches of the tripod, and beyond the border of the wheel, are erected 2 pillars, the upper parts of which are formed into screws. Four screw-nuts work, two and two, upon the screw part of these pillars, and, embracing the ends of a strong brass bar, K K, which they support, allow the height to be adjusted so as to suit the thickness of the work to be divided. To the near branch of the tripod a cross-piece, L, Fig. 1103, nearly the length of the screw-arbor and parallel to it, is firmly fastened. This carries upon its extremities 2 pillars similar to, but smaller than the others. Upon the strong bar, K K, at equal distances from the middle, are roller-bars fixed by finger-screws. They extend from the strong bar to the pillars in front, to which they are secured by double-nuts like the former. These 2 bars, M M, Fig. 1102, are bound together by a cross-brace at the remote end, and by another a little way beyond the centre. In no other part can crossing-pieces be allowed; for as they form the support for the apparatus that cuts the divisions uninterrupted motion along the whole line of the radius is required.

The cutting apparatus consists of 3 principal pieces, *a*, *e*, *o*, Fig. 1102. The first is a bridge which crosses the space between the bars, M, M, and to which it is attached at the ends by sliding sockets: these run along the bars, and can be clamped thereto at any part so as to suit the length of the radius of the instrument which is to be graduated. Two steel screws, with conical points, are tapped through the perpendicular ends of the bridges above the sockets, and by working in holes of the second piece, form an

axis or joint round which the latter has a free and steady motion. The third piece, the form of which, as well as of the second, is seen in the plan, has also steel screws with conical points tapped through its ends, and these, like the others, act in the middle piece, forming another horizontal axis parallel to the former, and in every respect like it. In Fig. 1102, the parts are extended, for the purpose of being better shown, into a position in which they cannot work. The best effect is produced when the middle piece is vertical, and the third horizontal. Sufficient freedom of action is found in this contrivance of Hindley's to produce a rectilinear motion of the pointril of at least one-third of an inch, a quantity fully sufficient for the required purposes. The part of the third piece next the centre, is that in which the pointril is placed. It is so contrived that its length below the piece may be varied at pleasure; that it may be turned round upon a horizontal axis so as to make any angle with the plane to be divided upon, and that its action may be viewed by a properly-attached magnifying-glass.

In Fig. 1103, a bar, attached to the same pieces that support the screw-arbor, to which it is parallel, and placed below it, together with a cock behind, bear the axis of a vertical friction-wheel, N. This wheel is placed so as to roll in contact with the under side of the limb of the engine immediately below the dividing-screw. Without this the action of the screw in the teeth of the wheel would occasionally produce a harsh jarring sound, but it is rendered mute by this contrivance.

A hardened and tempered steel arbor rises full 2 inches above the surface of the plate in the axis of which it is immovably fixed. In the other engines the axis is hollow, so as to admit arbors of different size to suit the centre holes of the instruments to be graduated; but as Mr. Troughton, in using this engine, divided only his own instruments, he made them, whether large or small, so as to suit his arbor, and thus avoided one source of uncertainty and error. This arbor is the principal connexion between the engine and the work to be graduated, and requires the most exact fitting. Tapped holes, variously arranged through the length of the 12 radii, furnish the means of applying holdfasts to prevent accidental circular derangement.

With this engine the operator can cut 24 strokes in a minute of time for hours together.

The history of machinery during the last half century elicits the remarkable fact, so illustrative of a very high state of civilization, that most of our machines have had impressed upon them the character of self-acting engines. Nothing shows more strikingly the supremacy of intellect than an arrangement of brute matter capable of performing mental operations with unerring precision. The analytical engine, by Mr. Babbage, and the self-acting spinning-mule, belong to this class; to which we may also add Mr. Simms's self-acting circular dividing-engine.

Although Troughton's engine, just described, was a great improvement on its predecessors, yet it required the constant attention of a skilful operator, at a great sacrifice both of time and of health, the effect of which was to add considerably to the cost of the instrument. Mr. Simms (of the firm of Troughton and Simms) therefore determined so to arrange the engine as to bring it under the yoke of some external moving power, such as a descending weight, a steam-engine, or a boy turning a winch, and having performed its work of dividing an instrument, to throw itself out of gear. The accompanying steel engraving represents an elevation of this engine, showing the apparatus for moving the engine-plate, and for cutting the divisions, together with the manner in which their operations are connected; and the following description will show in what respects it differs from E. Troughton's engine just described in detail.[1]

The circle or engine-plate is of gun-metal, 46 inches in diameter, and was cast in one entire piece by Messrs. Maudslay and Field. The centre of the plate is also peculiar; it being so arranged that it can be entered by the axis of the instrument to be divided, and the work thus brought down to bear upon the surface of the engine-plate. In former cases it was necessary, either to divide the instrument *originally*, which on account of the expense was seldom done; or to separate the part intended to receive the divisions from its axis and contiguous parts, in which state alone could it be placed upon the engine. The danger of detaching the instrument from its centre and framing is, that when reframed there is frequently a sensible excentricity; that is, the centre of the divided circle is not in the axis of rotation. This, however, does not lead to error, if two or more opposite readings be used. The great danger is distortion of the circle when the instrument is again put together. When the divided limb is only part of a circle, as in the sextant, any error of excentricity may become sensible, notwithstanding the care of the artist. In the present engine these difficulties are obviated, as already stated, by not dismounting the instrument.

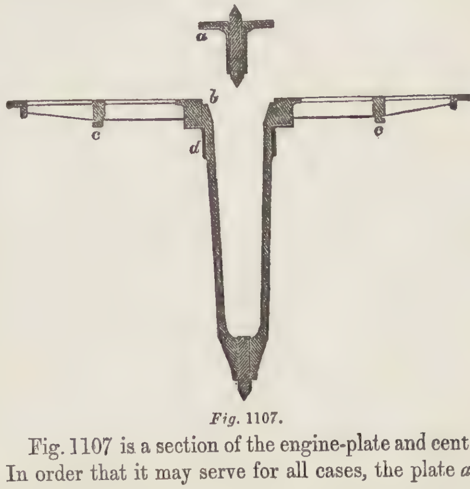


Fig. 1107.

Fig. 1107 is a section of the engine-plate and centre. In order that it may serve for all cases, the plate *a* is

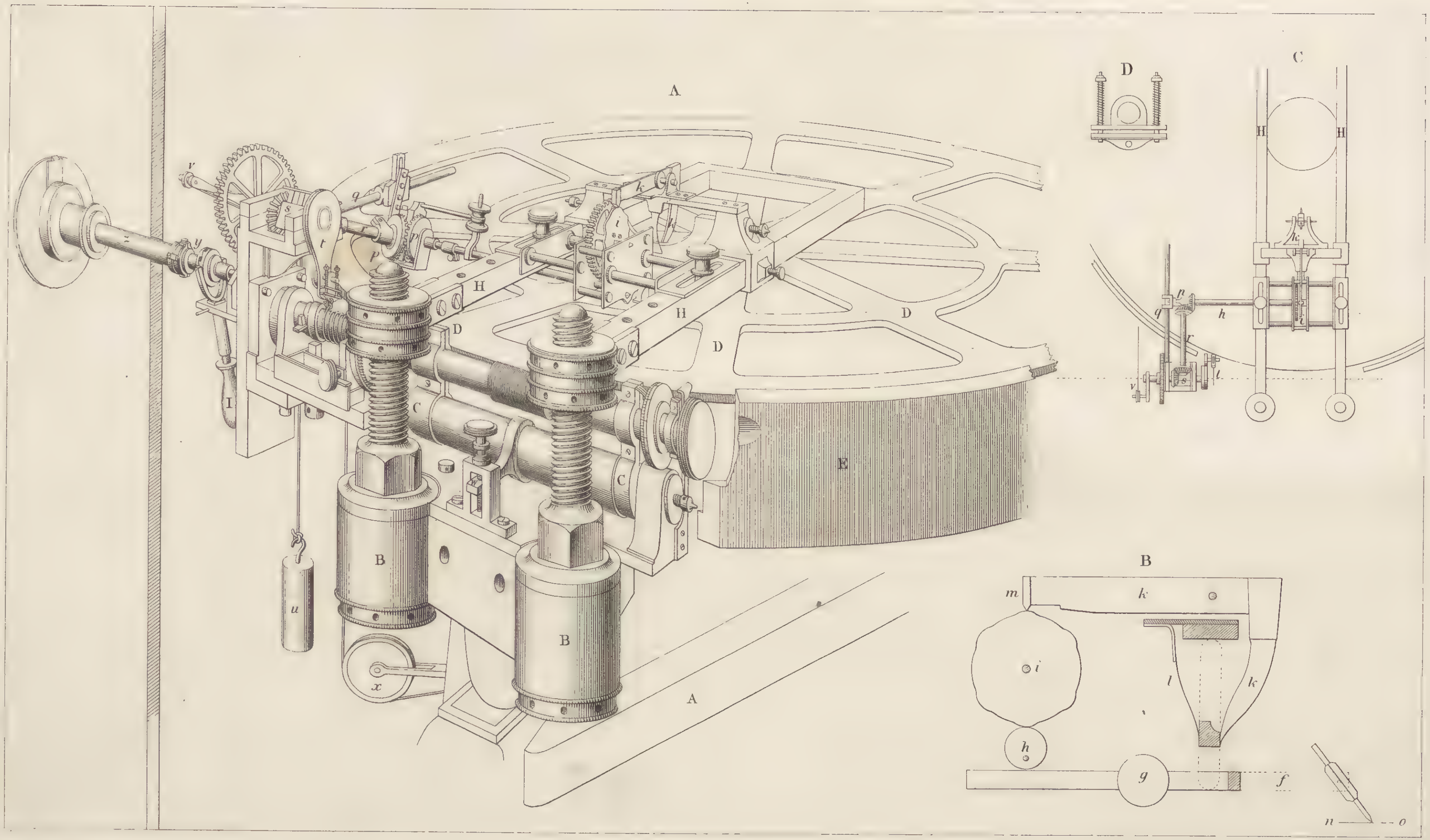
(1) The description of Mr. Simms's Engine is contained in the Memoirs of the Royal Astronomical Society, vol. xv. 1846.

truly fitted into the recess *b*, and its upper plane made to coincide exactly with the general surface of the plate. Steel arbors of various sizes, one of which is shown in the figure, are adapted to this central plate. Friction rollers bear against the projecting-ring *c*, which has a groove turned on the edge, around which a cord may be coiled, to overcome by a weight the inertia of the machine; but this has proved unnecessary. The centre terminates in a steel point, and turns in a collar of steel *d*, fitted into the centre of a massive tripod by which the machine is supported.

On the surface, and not far from the edge of the engine-plate, are two sets of divisions to spaces of 5 minutes; one upon a ring of silver, with fine lines for microscopic purposes, and the other upon the gun-metal face, cut strongly, so as to be easily seen without the assistance of a lens. There are also as many teeth upon the edge as there are divisions upon the face of the engine-plate, viz. 4,320; so that one revolution of the endless screw moves the circle through a space of 5 minutes. The circle was divided with extreme care; the first computation of the errors of the original points being merely made use of for the insertion of a second series of points, the errors of which, although exceedingly minute, were measured, computed, and tabulated in like manner; and from this second series the divisions were cut. The edge was ratched with a single circular cutter mounted in the endless screw-frame, and as each division in order was brought to coincide with the wires of a powerful microscope, the cutter was entered, and 3 circulations of the engine-plate completed the work.

The cutting apparatus is shown at B in the steel engraving, partly in section, and separated from its supports and other parts which conceal it in the engine: *e* and *f* are the two members of the cutting-frame (which is similar to Hindley's as described in Troughton's engine), but the tail of *f* is prolonged in order to carry the counterpoise *g*, by which the pressure of the point upon the work, and consequently the depth and width of the divisions, are determined, and also that the revolving excentric *h* may alternately lift the point from the work and allow it to descend upon it to cut the division: *i* is a plate with an undulating edge, by which the alternations of long and short strokes are regulated. This requires to be changed from time to time according to the nature of the work; the one represented is made use of in division to spaces of 5′, where the third and sixth lines have not only to be distinguished from the intermediate arcs, but also from each other, by their length. The motion of the plate *i* is communicated to the cutting-frame *f* by means of the bent lever *k k*, one extremity resting on the edge of the plate, and the other pressing against the front of the cutting-frame, contact being maintained by the spring *l*. A pinion upon the axis of *h* acts in a wheel upon the axis of *i*; and these are so proportioned that *h* makes 6 revolutions to 1 of *i*, a proportion that answers for 5′, 10′, 15′, or 20′, upon the circle under graduation, by varying the plate *i*. Now, supposing a division to have just been cut, and the excentric, by its revolution, to be about to lift the point from the work: this having been done, the end *m* of the bent lever descends the inclined plane, and the cutting point is thereby allowed to return from *n* toward *o*: in due time the motion of the excentric allows the point again to descend upon the work: the lifting of the end *m* of the lever by the next advancing protuberance, and the consequent pressure of the other extremity against the front of the cutting-frame, causes another division to be cut. The respective lengths of the divisions are obviously regulated by the radii of the several projections on the edge of the plate. This cutting apparatus is connected with the endless screw for working the engine-plate by means which are shown in plan in Fig. C, and in perspective in Fig. A, of the steel engraving. In C, *h* represents the axis of the excentric; *p*, a pair of bevelled wheels fitted to a box, which slides along the bar *q*, in order that the cutting point may be adjusted to the required radius, and for the same purpose the bar *r* consists of 2 tubes, sliding within each other, and capable of being fixed at any point by means of an external clamp. Another pair of wheels, at *s*, changes the direction of the motion, which now becomes parallel to the endless or engine-screw, and the shaft to which the last bevelled wheel is attached is turned by the external machinery. Each extremity of the shaft *t v* terminates in a crank: that at the end *t* is connected by the eye, Fig. D, to the cord coiled round the spiral barrel, and thus communicates its motion to the endless screw; the other merely raises a weight, which, in its ascent, checks the accelerating tendency of *t* during the return of the ratchet-wheel, and in its descent acts as an auxiliary in giving motion to the endless-screw, thereby preserving uniformity throughout the whole action, which would otherwise be unequal and interrupted. The spiral barrel and ratchet-wheel are similar to those described in Troughton's engine. The wheels at *p* are drawn in Fig. A, of equal size, in which form they serve for graduation into spaces of 5′, which is the most usual upon work where the subdivision is effected by reading micrometers, and also in many cases where verniers are used. For other spaces these wheels must be proportioned, or the same thing may be effected by increasing the length of the crank.

In the steel engraving all the essential parts are given, which serve for moving the engine-plate, and for cutting the divisions. A is a branch of a strong well-braced stand of wood, upon which the whole machine is placed. B B, the metallic tripod, in the centre of which the engine-plate turns, and to which all the superior parts of the machine are firmly attached. C C, the endless-screw frame, which turns upon finely polished steel pivots. The screw is kept in contact with the edge of the engine-plate with a proper degree of pressure by a spiral spring acting under the lever *w*, and can, when necessary, be discharged from action by the screw opposed to it. D D are portions of the engine-plate, and E represents



GRADUATION. SIMMS'S SELF ACTING CIRCULAR DIVIDING ENGINE.

a hoop of mahogany by which it is surrounded, and its edge protected from injury. H H are parallel bars, to which the cutting apparatus is fastened. (See also Fig. C.) *p*, *q*, *r*, *s*, and *t*, exhibit, as before, the parts connecting the motion of the cutting-frame with that of the endless-screw; but in the steel engraving, the crank, and its connexion with the cord wound round the spiral barrel, are more clearly shown than in the figure, where they are represented only in plan. The eye (Fig. D) by which this connexion is made, consists of 2 pieces, one to fit upon the crank, and the other to fasten to the cord: these parts are kept together by spiral springs, which by their elasticity prevent the jerk that would otherwise be given at each revolution of the crank. This part is also clearly shown in the steel engraving. *u* is the weight connected with the crank *v*; the opposing weight, or that to which the cord proceeding from the spiral barrel is fastened, is within the framework of the stand: the cord, in its progress towards it, passes over the pulley *x*, and also over another pulley within the stand.

A pair of plates, with serrated edges, is shown at *y*: these plates serve to establish the connexion between the engine within the apartment and the driving machinery without. One of the plates is fastened to the cylinder *z*, which passes through the wall of the apartment, and the other can be thrown in or out of action by the handle I; so that the connexion can be made and broken in a moment.

The method by which the engine can discharge itself from action, when it has completed its work, remains to be noticed. Against the handle, I, a spring is made to exert a pressure, the tendency of which is to detach the engine from the external machinery: this is opposed by a trigger turning on very delicate centres, and carrying a friction-roller at its other extremity. Upon the engine-plate, a small well-polished wedge is fastened, which, as it circulates, passes under the friction-roller, which it lifts, and consequently discharges the bolt at the other extremity. This apparatus of course requires careful adjustment before the operation of dividing commences.

In the year 1831 Mr. Andrew Ross received the Gold Isis Medal and fifty guineas from the Society of Arts for his improved method of dividing instruments, and for his circular dividing-engine. We regret that we cannot, within our limits of space and illustration, do more than give a general idea of the principle of this engine. To do full justice to it would require us to copy the numerous illustrative engravings which accompany Mr. Ross's paper in the 48th volume of the Society's Transactions.

It will be remembered, that in Ramsden's, and also in Troughton's engine, the circle which carried the instrument to be graduated was moved round by the teeth of an endless screw working in corresponding notches cut in the edge of the circle, and the endless screw was made to turn on its axis by a catgut band passing round a spiral in the same axis, and fastened below to a treadle which was worked by the foot. Mr. Ross objects to the serrated cylindrical screw on account of the great pressure required being inconsistent with those delicate operations so necessary to accuracy in such a machine; and he also thinks that variations in density in the steel screw, and porosity and other inequalities in the cast-metal circle, are likely to lead to error. He therefore gets rid of the driving motion of the screw, and obtains a rotary motion by an independent apparatus: he can also stop the circle at its precise angular position by the contact of plane and spherical surfaces of hardened steel. A more steady motion is given to the circle, and it also admits of being so adjusted that the inequalities produced by the wear of the parts may be obviated.

The circle C, Fig. 1108, turns on its centre on a vertical axis, the lower extremity of which rests in a cup at one end of a lever, and a counterpoise being hung at the other end, the axis is thus pressed upwards and diminishes the pressure of the circle on the rectangular cast-iron frame which supports it, a portion of which is shown at A B. Around the circle are screwed 48 projections, *a a*, through which

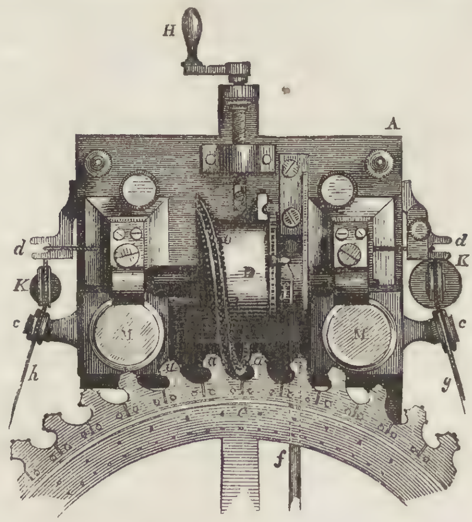


Fig. 1108. MR. A. ROSS'S DIVIDING ENGINE.

are passed capstan-headed screws parallel to the plane of and tangent to the circle. The ends of the screws are hardened and ground flat and square to the axis, and the screws themselves may be fixed in any position by means of tightening screws. At one end, A, of the rectangular frame, a sliding apparatus carries a cylinder, D, turning on a horizontal axis: on the surface of this cylinder is a worm, or spiral projection, *b b*, which enters between the projections *a a*, and the distance between the two turns of the spiral is rather greater than the breadth of one of the projections, *a*. A number of steel screws pass through the spiral thread; and the ends of these screws are turned in the form of hemispheres, so that after every movement of the circle C, and of the spiral *b b*, the engine is held in a state of rest by the abutment of the hemispherical end of one screw against the flat end of the other. On the outer rim of the circle C, below the projections *a*, is a groove in which an

endless catgut band, G H, passes round, moving over pulleys; first over c, a fixed pulley; then under a movable pulley, from which is suspended a weight, K: it then passes above the machine to a notch at d in the direction $d\,d$. Four pillars, of which M M are two, rising from the frame A B, support a stage which carries the cutting apparatus, and this is so formed with joints as to allow the tool to be moved up or down, or in the direction of a radius of the circle C, but not on either side of that radius: there is also a contrivance for determining the length of the lines of division. By moving one end of a lever at the opposite extremity of the frame A B, a bar, $f\,f'$, which is attached at one end to that lever, gives motion to a catch or click so as to cause a ratchet-wheel to turn on its axis, and thus give the requisite movement to the cutting tool: the other extremity, f', of the bar, by turning a lever on a horizontal axle containing within it the axle of the cylinder D, allows a catch or click to turn a ratchet-wheel on the latter axle, and, with it, the cylinder itself; and thus a side of the spiral projection, $b\,b$, is removed a little way from its position when in contact with one side of a projection, a. The first lever being moved back again, a spring, which had previously pressed against the catgut band, is drawn off; and thus, one of the weights K, by drawing down the band and pulley above it, gives a small movement to the circle C, and brings the side of a projection, a, again in contact with the side of the spiral. According to the place at which the bar $f\,f'$ is applied to the lever on the axle of D, the catch may pass over any required number of the teeth of the ratchet-wheel, and thus the circle C may be turned through any angle consistently with the values of the divisions intended to be cut.

The original divisions on the circle C are made on silver studs let into its surface, and the screws passing through $a\,a$, $b\,b$ are so adjusted by means of their capstan-heads, that if the end of a screw in $b\,b$ is in contact with the screw in any one of the projections a, one complete revolution of the spiral $b\,b$ may bring the end of the screw in the next projection, a, in contact with the same screw in the spiral. The corresponding movement in the circle is equivalent to the interval between two of the original graduations; and the movement is verified by the primitive divisions coming successively to a wire in a microscope.

3. *Original graduation.*—We now come to notice, very briefly, the art in its highest order, an art which for ages was carried on in secrecy and silence by men of science as well as by artists. It has been described as one of the nicest operations of manual labour, in which few are qualified to succeed: indeed, the importance of the art may be estimated from the high consideration in which the successful artist is held by those who are qualified to appreciate his labours. The engines described in the last section are mere copying engines, and we believe it is not decided whether circles from the same engine are facsimiles. But the work of original graduation is so arduous, that, as Mr. Simms remarks, "to copy the divisions from a circle of large diameter which had been graduated with extraordinary care, upon work of smaller dimensions, would in general be more satisfactory than original graduation. The latter process consists of several successive steps, in any or all of which a certain amount of error may escape detection. In general, such errors go far to balance one another; but there will be parts in almost every work where faults of graduation appear which can only arise from an accumulation of minute errors."

The earliest methods of dividing of which any detailed account is given, are those by Hooke and Römer. Hooke's method consisted in racking the edge of his quadrant with an endless screw, and to use the revolutions and parts of the screw as a division; but this method was found in practice to be very defective unless checked and corrected by independent divisions. Römer's method was *stepping* a fixed distance throughout the whole of his arc, the distance being so proportioned to the radius of the arc, that it was very nearly equal to one of the smaller divisions required, the total length of the arc being in this case disregarded, as any number of divisions were converted into degrees and minutes by a table calculated for the purpose.

Hindley's method was nothing more than an original, highly ingenious method of stepping. It is described in the following letter which he addressed to Smeaton on the 14th of November, 1748; and the reason why it was not published until 1786 was, that Hindley entrusted it as a secret to Smeaton. He says:—"First choose the largest number you want, and then choose a long plate of thin brass: mine was about 1 inch in breadth and 8 feet in length, which I bent like a hoop for a hogshead, and soldered the ends together, and turned it of equal thickness upon a block of smooth-grained wood, upon my great lathe, in the air, (that is, upon the end of the mandrel): one side of the hoop must be rather wider than the other, that it may fit the better to the block, which will be a short piece of a cone of large diameter: when the hoop was turned, I took it off, cut and opened it straight again. The next step was to have a piece of steel bent into the form as per margin, [Fig.1109,] which had two small holes bored in it of equal bigness, one to receive a small pin, and the other a drill of equal size. I ground the holes after they were hardened, to make them round and smooth. The chaps formed by this steel plate were as near together as just to let the long plate through. Being open at one end, the chaps so formed would spring a little, and would press the long plate close by setting in the vice. Then I put the long plate to a right angle to the length of the steel chaps, and bored one hole through the long plate, into which I put the small pin; then bored through the other hole; and by moving the steel chaps a hole forward, and putting in the pin in the last hole, I proceeded till I had

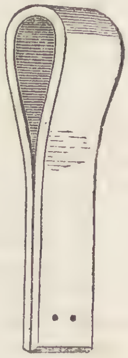


Fig. 1109.

divided the whole length of the plate. The next thing was to make this into a circle again. After the plate was cut off at the end of the intended number, I then proceeded to join the ends, which I did thus: I bored 2 narrow short brass plates as I did the long one, and put one on the inside and the other on the outside of the hoop, whose ends were brought together; and put 2 or 3 turned screw-pins, with flat heads and nuts to them, into each end, which held them together till I riveted two little plates, one on each side of the narrow plate, on the outside of the hoop. Then I took out the screws, and turned my block down till the hoop would fit close on; and by that means my right line was made into an equal divided circle of what number I pleased. The engine-plate was fixed on the face of the block, with a steel hole fixed before it, to bore through; and I had a point that would fall into the holes of the divided hoop; so by cutting shorter, and turning the block less, I got all the numbers on my plate. I need not tell you that you get as many prime numbers as you please; nor that the distance of the holes in the steel chaps must be proportioned to the length of the hoop."

Graham was the first to point out the fundamental principle of original graduation, viz. that you can divide a given line accurately into two parts, but not into 3 or 5 equal parts. "If a line or an arc is to be bisected, the points of the beam-compass are placed *nearly* at the distance of half the line, or the chord of half the arc between the dots. One point is placed in one dot, and a faint arc is struck with the other point towards the distant dot, and this operation is repeated with the second dot as a centre. The two faint arcs will either include a small space, or leave a small space between them, which can be most accurately divided with a pointer by the hand, aided by a magnifying lens."

The Duc de Chaulnes, after perfecting the micrometer-microscope for reading off the divisions of astronomical instruments, first showed how it might be used in actual dividing. Two microscopes, having cross wires in the foci of their eye-glasses, were fixed to a frame, and considered as the points of a pair of beam-compasses: these were extended to a diameter of the circle, and two temporary pieces of brass, with divisions on them, were attached to the circle by means of wax beneath the microscope, so that the divisions bisected the crosses in them: the circle was then moved half round, and, if required, the position of the micrometers and pieces of brass was changed, and the operation repeated, until they were diametrically opposite. A cutting point was then placed over one division, and a fixed microscope over the other, so that when any division was brought to bisect the cross in the microscope, the cutting point made one diametrically opposite. By the process of trial and adjustment with bisections and trisections, the circle was divided into spaces of 10°: then, by obtaining the arc of 9° by trial in the arc of 180°, the circle can be divided into spaces of 1°, and by similar means into smaller spaces if required.

Ramsden appreciated the advantages of the micrometer-microscope, and used it for reading off the divisions of his circles and theodolites. Edward Troughton combined Graham's method of perpetual bisections with the Duc de Chaulnes's mode of reading off. Troughton's method is thus concisely stated in a short, but masterly article on Graduation, in the *Penny Cyclopædia*:—"We will suppose that a circle is to be divided originally. After the edge of the circle is very carefully turned upon its own centre, a small circular roller, 16 revolutions of which carry it exactly round the circle, is prepared and so fitted to the circle by a radial frame joining the two centres, that, on turning the frame round, the roller is also turned in an opposite direction by friction between the edges of the roller and circle. The roller is divided into 16 parts, and a microscope placed over the divisions, and as each division comes under the microscope a fine round dot is marked upon the circle, which thus receives an approximate division into 256 (or 2^8) equal parts. Troughton expected, that as the roller could be carried round the circle any number of times without over or under-lapping, it would also mark out equal portions at each revolution; but he found himself mistaken, and he therefore proceeded to examine the dots optically. Two microscopes, A and B, are fixed above the circle, nearly in a diameter, and the dots which are to determine the divisions 0° and 180° are bisected by them. The circle is then turned half-round, and dot 180° brought under A; if 0° at the same time falls exactly under B, the points are diametrically opposite, if not, the quantity and direction of the error is measured by the micrometer of B, half of which is evidently the error of dot 180°. The microscope B is then shifted and fixed over dot 90°, while A bisects 0°. By a quarter revolution of the circle, 90° is brought under A, and 180° under B, and the error, if any, measured and noted. In like manner the error of dot 270° is detected; after which the microscope B is again shifted and fixed over dot 45°, when the errors of dots 45°, 135°, 225°, and 315°, are determined. It is easily seen that this is exactly Graham's principle of perpetual bisection, only using an *optical* beam-compass instead of one with points, and registering the errors of the dots instead of cutting actual divisions. In this way Troughton proceeded by continual bisections to note the relative or apparent errors of the 256 dots. His next step was to compute the actual or true error of each dot, and to form a table. Suppose that in examining the 180° dot he found that the arc from 0° to 180° was less than the arc from 180° to 360 by 20″, he would conclude that the dot 180° was 10″ behind its true place. Again, let the arc from dot 0° to dot 90° exceed the arc from dot 90° to dot 180° by 30″. If 180° were right, 90° would be too forward by 15″; but as 180° is 10″ behind its true place, 90° will, on this account alone, be 5″ behind [forward], and therefore, on the whole, will be 10″ too forward. The true errors of each of the 256 dots being thus computed, Troughton returned to the roller, and by help of a small sector, which revolved with it, and gave him an enlarged

scale, enabling him at the same time to reduce the division into 256 parts into 360° mechanically, proceeded to cut the actual divisions on the circle. . . . . It is not worth while to divide a circle *originally* which is less than 2 feet in diameter. Very great care must be taken that the pivots, on which the circle turns, shall be perfectly true and sound. The circular line to be divided, and the rim on which the roller moves, are respectively drawn and turned from these pivots, and the figure of neither is a circle unless the pivots be so. The large collar of the mural circle on which the rim is turned is of steel, and several inches in diameter. It often happens that hard knots occur in the steel which ordinary tools will not touch, and it would be prudent in the artist to perform the finishing part himself with a diamond."

GRAIN, (from *granum*, a seed,) an old measure of weight, the smallest of those in use: it is about the weight of a seed of wheat-corn. By a statute of Edward III. (A.D. 1266,) it was enacted that 32 grains of wheat taken out of the middle of the ear and well dried, should weigh a pennyweight, of which 20 should make an ounce, of which 12 should make a pound. The pound troy of this period, therefore, consisted of 7,680 grains; but that afterwards adopted had only 5,760, because the pennyweight came to be divided into 24 instead of 32 grains. [See WEIGHTS AND MEASURES.]

"The weight of one grain is obtained for practical purposes without difficulty, by weighing a thin plate of metal of uniform thickness, and cutting out by measurement such a proportion of the whole plate, as should give one grain. But a much better plan is, to draw a given weight of ductile metal into very thin wire, and to cut from the wire that length which is the same proportion of the whole length as a grain is of the whole weight. In this way pieces of wire are obtained for chemical purposes, which weigh only the thousandth part of a grain; and even less weights might be obtained if it were necessary."

GRANITE. The composition and varieties of granite have been described in our introductory essay, (page lxxix.) but it remains to add some particulars, as to the mode of extracting and working this valuable substance, and its use as a building material and for ornamental purposes. Strange to say, the systematic use of granite in these islands is comparatively recent. The rounded outlying masses of granitic-rock which were found on the surface, were long employed both in Aberdeen, and at Dartmoor, (our two great depositories of granite,) for building purposes; but until 1730 in the former case, and 1820 in the latter, the squaring and dressing of this intractable material, and the opening of quarries to obtain a larger supply, had been scarcely thought of. The first building of any large size erected in Aberdeen with dressed or squared stones of granite, was Gordon's Hospital, commenced in 1739; and even in this case, sandstone was employed to form the lintels and facings. The good people of Aberdeen were not fully alive to the value of the rough material so plentifully scattered around them, until about the year 1760, when the profits arising from its conveyance to London as paving-stones opened their eyes to its importance, and they found that the surface-granite could not meet this demand, and that quarries must be opened to supply it. In like manner, the detached blocks lying about on Dartmoor were used in the neighbourhood for many years previous to 1820, when quarried granite was first brought into the market by the Haytor Granite Company. The Foggintor quarry, on Dartmoor, worked by this company, is in some places 100 feet high, and is worked in benches, or like a huge irregular flight of steps. The method of detaching the masses of granite-rock from their natural beds,[1] is first to determine the points of least resistance, and then to sink holes in those points vertically or inclined, as circumstances may require; the diameters of these holes being regulated by the mass and the amount of resistance, and their depth by the thickness of the blocks to be detached. The holes are sunk by means of an iron rod, ending in a chisel-shaped edge of hardened steel. The rod is held by one man, who changes its position after every blow from the sledge-hammers of other men who stand around. These holes, when sufficiently deep, are charged with gunpowder, for the purpose of blasting the rock; the ordinary process of tamping confines the powder, and the fuse communicates the blast. This operation is most perfectly performed, where the smallest amount of powder will remove the largest mass of rock with the least breakage. From three to five thousand feet have been removed at one discharge. [See QUARRY.]

To bring these rough masses into shape, lines are drawn at the places of the proposed division, and holes bored along them, five or six inches apart, and two or three inches deep, by means of a jumper. Each hole is then filled with two half-round pieces of iron, called *feathers*, with an iron-pointed wedge between them, and these wedges are gradually and equally driven until the stone splits. The split is in general tolerably flat, but should it be otherwise, the large projecting portions are removed by boring holes sideways, and again using the feathers and wedges; or smaller flakes are *spalled* off, or scaled by means of axe-formed hammers. The last operation, so far as the quarry is concerned, is *scabbling* the surface with heavy pointed picks. The blocks are then ready for the mason. A process not unlike this is adopted by the Chinese, for the squaring of the granite in the neighbourhood of Hong Kong. The granite rock which formed the crust of the earth near the main land of Cow-loon, seems by some tremendous action from below to have been raised up from its bed, riven into fragments of every kind of shape and dimension, and left in that new arrangement to undergo the weathering effects of the atmosphere. In the course of time, the smaller pieces were dis-

(1) This quarry forms a remarkable exception to the rule which generally applies to the harder crystalline rocks, for here the granite occurs in stratified beds, following pretty nearly the slope of the hill, and becoming thicker and more nearly horizontal the deeper they are situated.

integrated into a quartzose sand, while the larger were merely rounded and polished by the same action which reduced their fellows to powder. Large masses lie embedded in sand, and at sufficient intervals to allow the hewer conveniently to attack them with his hammer and wedges. He first draws a line by means of an inky thread, which he manages with his hand and foot; then makes holes along the line about a foot apart, by means of his hammer and chisel,—a very slow and tedious operation; finally he inserts iron wedges, and passes three or four times from one end to the other, driving the wedges in succession, until at length the hard rock yields and falls asunder, as if it were only a piece of limestone. A block thus removed is cut up into smaller slabs by a renewed application of the hard chisel and the iron hammer, the wedge and the iron maul or beetle, while the irregularities of the surface are beaten off in the same way.

As a building material, the granite of Aberdeen is considered the best which our island affords. Its light bluish white tint is not liable to be affected by variations of weather, and when highly dressed, its appearance is not unlike that of the best white marbles. It is remarkably fine-grained, and on that account is of greater absolute strength than many other granites which may be more varied and pleasing to the eye. Magnificent stones as it respects size have been supplied from the Aberdeen quarries, such as the pedestal of the bronze statue of the Duke of Bedford in London, and the columns which are placed as piers in the vaults of the Custom House. The price of granite varies with the size of the block, and such stones as the above cost in their rough state at the quarries from five to eight, and in some cases ten shillings per cubic foot. Seven hundred thousand cubic feet of squared granite were supplied by the Aberdeen quarries for the docks of the naval arsenal at Sheerness, at 4*s.* 11*d.* per foot, including coasting duty. The tender for Aberdeen granite to the Fishmonger's Company, when their new Hall was about to be erected, was to deliver it in London at the following prices:—For a stone weighing 15 tons weight, 10*s.* per cubic foot; for one weighing 12 tons, 9*s.* ditto; 9 tons, 8*s.*; 6 tons, 6*s.*; 5 tons, 5*s.* 6*d.*; 3 tons, 4*s.* 6*d.*; 2 tons, 4*s.*, per cubic foot. The vast strength of the Aberdeen granite may be estimated by the fact that a half-inch cube of the best granite required a force of 24,556 lbs. to crush it, which force was supplied by the hydrostatic press.

The Aberdeen granite has now to sustain great competition with that of Devonshire, from the quarries of the Haytor Company. This is also light of tint, fine of texture, and obtainable in very large blocks. A stone tramway was early constructed to enable it to be shipped at Teignmouth, and the completion of the Plymouth and Dartmoor railway afforded ready transport for the granite of the western face of the moor, from Foggintor, and other places adjacent. The facilities with which these quarries are worked, are therefore very great. Strong timber stages with travelling frames, and upon the frames powerful traversing crabs, have been constructed, to avoid the labour and delay of lifting by the ordinary means of derricks and cranes. The travelling frames, with the crabs upon them, can be transferred from one line of scaffold to another, so that power may be accumulated to any extent on one stage, so as to operate on blocks of extraordinary size. And such can be obtained from these quarries, the horizontal disposition of the rock allowing of the removal of stone of fair forms, and of the largest size. As an instance of the durability of Dartmoor granite, it is stated that a slab, which had been used as a foot-bridge from time immemorial, on being turned up, exhibited on the other side a Roman inscription, showing it to be at least two thousand years old.

The application of granite and porphyry to purposes of ornament, is the work of recent times, so far as modern nations are concerned; but those who have examined the saloon of Egyptian antiquities, in the British Museum, and still better, those who have been privileged to inspect the remains of Egyptian sculptures on their primitive sites, will have viewed with wonder and interest the result of the immense labours of that people, in bringing to a high degree of finish, works, in these, the most intractable of all materials. After the lapse of three thousand years, these works exhibit a degree of polish, and delicacy of detail, which shows how well the material is fitted to brave the attacks of weather, and of still ruder invaders. The idea of employing the chisel on such hard and nearly imperishable materials, appears to have originated with the Egyptians, and despite of the enormous difficulties with which they have had to contend, they have succeeded in giving softness of expression and a fleshy appearance to the features of their colossal heads.

In modern times, the best works in porphyry and granite have been executed, until quite recently, by the Swedes. Their success in the fabrication of vases, slabs, &c. in this unpromising material, has made them celebrated in Europe. The beautiful proportions and high finish of the porphyry vase, exhibited by Sweden, in the nave of our Great Exhibition, attested the skill of the sculptors. The Swedes, after bringing the objects as near as possible to the required form with a pick, mount them in lathes driven by water power, and finish by grinding them with other lumps of porphyry, supplied with emery and water; the machinery being kept in action, with fresh gangs of men, day and night.

Some fine specimens of porphyry may be seen at the Polytechnic Institution, Regent Street. Among others, a table 5 feet 10 inches in diameter, tastefully inlaid with numerous pieces of various colours. The table stands on a finely fluted pedestal, and it is said that the whole work occupied five men for the period of seven years. Two splendid porphyry vases five or six feet high are to be seen at Chatsworth. These were presented to the Duke of Devonshire by the Emperor of Russia, as a specimen of a flourishing manufacture which has sprung up in a barren valley

where the porphyry was found. The beautiful porphyry of Cornwall might be readily converted into similar articles of elegance.

The process of polishing granite is more tedious and difficult than porphyry, on account of the unequal hardness of the particles. Nevertheless, of late years, numerous vases, and other circular and ornamental objects, have been executed in the most admirable manner in polished granites and elvans, which occur of various colours and degrees of hardness. The first persons in the British isles to accomplish this task, were the Messrs. Macdonald and Leslie, of Aberdeen, who introduced highly polished granite as a domestic ornament in halls and saloons, and also fabricated from the grey granite of Aberdeen, and the rich red granite of Peterhead, an endless variety of ornamental articles. The grey is of close grain, and contains more mica than the red. The red granite abounds in felspar and quartz, intermingled with small specks of mica, and bears a strong resemblance to the syenitic rock from which the finest Egyptian monuments are made. Both are susceptible of a fine polish, which they retain unimpaired by the weather. Professor Traill, describing a visit to the works of the firm above named, says, that the blocks of granite, which can be obtained of almost any size free from flaws and imperfections, are sawn asunder by machines moved by a fourteen-horse power steam-engine. The saws are of soft iron plates, secured in a frame, and operate on the stone by means of quartz-sand and water, applied as in slicing marble. No emery is requisite, the particles of siliceous sand being sufficient to cut the quartz, the hardest material in the granite. Frequently, fourteen saws are used in a single frame; occasionally eighteen are at work on a single block of stone. The progress of the work is very slow: it requires a whole day to cut a groove two-thirds of an inch in depth in the granite. The slabs, when cut, are polished by moving one over the other, by appropriate machinery, siliceous sand being first interposed, and then emery of various degrees of fineness, until the required lustre is obtained.

The first dressing of the granite blocks into parallelopiped, cylindrical masses, or other curved forms, is performed by handpicks, with short handles and heads about 4 lbs. in weight, which the workmen, from long habit, wield with great dexterity. The surfaces are then made regular by means of well-tempered chisels, urged by iron mallets; the chisels require a very particular temper, which must be neither very hard nor very soft, else they would either lose their edge by chipping, or fail to cut the stone. In the more delicate kinds of work they require frequent sharpening. The chisel is held obliquely to the stone, and very small particles are removed at a time.

In polishing curved or circular forms, as vases, the article is fixed in a well-contrived lathe, and whirled round by machinery, while the sand and emery are applied to the surface by means of thick plates or bars of iron, previously forged to the various curvatures. A large vase, for instance, was first prepared by the chisel, its graceful curves being in that way accurately cut; while iron bars from an inch to an inch and a quarter in thickness, neatly forged to its various curves, were ready to be applied to it, when it was fixed in the lathe.

By these various means, articles of great beauty and elegance are produced; chimney-pieces, tables, seats, pedestals, vases of classic forms, mural tablets, and altar-tombs. The lettering on monuments is executed with perfect neatness and precision by first tracing the inscription with a dark or light crayon according to the colour of the stone, then tracing the outline by light strokes of a fine-edged chisel held nearly vertically. The lines are then deepened by a succession of similar blows, while the chisel is held very obliquely, removing the stone in the state of powder, so as to avoid chipping. Roman capitals are thus easily formed, but Old English or German letters are more difficult. These, however, are carved in granite with the same precision.

Campbell's monument to the late Duke of Gordon was transferred from the model to the granite, by Messrs. Macdonald and Leslie. It is the first specimen of a British statue of a single block of granite, and leaves no doubt of the good effect attainable in this substance, under modern treatment and appliances. This statue is a great ornament to the city of Aberdeen, as is also a noble fountain of Peterhead granite which stands in the market-house. This is an octagonal basin, constructed of polished blocks, from the centre of which rises a shaft ten feet high, supporting two circular cups or shallow vases, one placed over the other. The lowermost is formed out of a single block 7 feet 3 inches in diameter, and the upper has about half that width. A constant jet of water rises from the centre of the upper cup, flows over its edges into the lower vase, which again overflows in a thin sheet of limpid water into the basin below, whence water is drawn for the purposes of the market. Notwithstanding the labour of workmanship, granite objects are produced at a very moderate cost. The beautiful fountain just described was erected at a cost of only two hundred pounds. Polished slabs can be furnished at from twelve to fourteen shillings the square foot.

This material greatly exceeds marble in durability, especially in a climate like ours. Marble loses its glossy surface and contracts greenish stains, but granite retains its polish under all atmospheric influences, and does not become stained by vegetation. An inscription in granite, unless wantonly mutilated, may convey information to distant ages. Four granite columns, bearing a very high polish, ornament the King's Library, British Museum. There is also a highly interesting collection of polished ornamental works in granites, elvans, marbles, serpentines, &c. in the Museum of Practical Geology, together with a large number of six-inch cubes of the same, which form part of the series of building-stones examined by the Commissioners, previous to the building of the New Houses of Parliament. The Institution of Civil Engineers has also a collection of granites.

GRAPHITE. See CARBON, page 316.

GRAVER. See ENGRAVING—GRADUATION, &c.

GRAVITY, SPECIFIC. Every substance in nature has, under the same circumstances, a weight *specific* or peculiar to itself; or, in other words, the same volumes or bulks of different substances contain variable quantities of matter. The comparative weights of equal bulks of different bodies are called their *specific gravities*, and the standard of reference is pure water at the temperature of 60° Fahr.

The specific gravity of a liquid is usually taken by means of a *specific gravity bottle*, graduated so as to contain exactly 1,000 grains of pure water. If this be filled with spirits of wine, and weighed in a balance, (together with a counterpoise for the weight of the bottle, which of course is constant,) it will weigh considerably less than 1,000 grains: in fact, the bottle will contain only about 917 grains of proof spirit; therefore, taking the sp. gr. of water as unity, 1 or 1·000, the sp. gr. of spirits of wine is 0·917. If, on the other hand, the bottle be filled with sulphuric acid, it will weigh about 1,850 grains: whence the sp. gr. of sulphuric acid is said to be 1·850.

In taking the specific gravity of solids, advantage is taken of the important fact, that when a solid is wholly immersed in water, it displaces a bulk of that liquid exactly equal to its own, and the solid appears to lose in weight; that is, it is supported by the surrounding water with a force exactly equal to the weight of the water displaced: hence, the difference of its weight in water from that of its weight in air, must be the weight of an equal bulk of water. Hence the rule for taking the specific gravity of a solid is, to weigh the solid in air, and afterwards in water, and having found the deficiency of the latter weight, to divide it by the former, and the quotient will be the required specific gravity. For example, a lump of glass is found to weigh in air 577 grains; it is then suspended by a horse-hair from the bottom of the scale pan, and immersed in a vessel of pure water, when it is found to weigh 399·4 grains; the loss therefore, or the weight of an equal bulk of water, is 177·6 grains; then 177·6 : 1 : : 577 : 3·2, which is the sp. gr. of the glass.

Solid bodies lighter than water, such as cork, may be weighed by attaching to them a mass of metal or glass, previously balanced in water for that purpose, which causing them to sink, the same method is adopted with the combined mass as in the example just given.

The specific gravity of a liquid is sometimes taken by an instrument termed a *Hydrometer*, the principle of which may be thus illustrated. A bulb of glass or other substance, immersed in water, is buoyed up by a force equivalent to the weight of an equal bulk of water; so, when immersed in any other liquid, it will be supported by a pressure equal to the weight of a similar bulk of that liquid. Thus, the above mass of glass lost 177·6 grains by immersion in water, and only 149 grains in spirits of wine: consequently these two amounts are the weights of equal bulks of water and spirit; therefore, 177·6 : 1 : : 149 : 0·839, the sp. gr. of the spirit.

The hydrometer is a hollow ball of glass or metal, with a weight below it, and a slender graduated stem above, so adjusted as to float at a particular mark in pure water. When immersed in a lighter liquid, such as spirit, the lateral pressure of the fluid particles which supports it being diminished, the bulb sinks, till a portion of the stem becoming immersed, its weight is decreased, and the balance again restored. The instrument may be adjusted to different liquids by movable weights, while the graduations of the scale are made to express the specific gravities by the degree to which it sinks.

Fig. 1110 represents Sikes's hydrometer, in which B is a brass ball, with a loaded stem C D, at the bottom, while above is a flat stem A B, graduated into 11 equal parts, each of which is subdivided into two. Eight circular weights (of which one is shown separately) are adjusted to the instrument: a slit cut in each admits the slender part C of the lower stem into the hole in the centre of the weight, and thus the instrument can be used in liquids heavier than water, but not in such as will corrode the instrument. A set of tables accompanies the instrument, by which the specific gravity of a spirit is easily ascertained, after observing the degree upon the stem to which it sinks. [See ALCOHOL.]

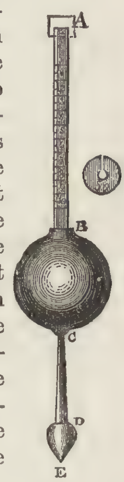


Fig. 1110.

The specific gravities of aëriform bodies are ascertained by weighing them with certain precautions as to moisture and pressure in a thin glass globe or flask fitted with a stop-cock. The standard of comparison is dry atmospheric air at the temperature of 60° and 30 inches pressure.

The following table from Daniell's Chemical Philosophy, shows the weight of 100 cubic inches of the lightest and heaviest known forms of matter; of the same quantity of atmospheric air; and of water in its three physical states. The specific gravity of each, compared with air and water, is also shown.

	Cubic Inches.	Weights.	Sp. Gr. Air being 1.	Sp. Gr. Water being 1.
Hydrogen	100	2·138 grains	0·0694	0·0000846
Air	100	31·000 —	1·0000	0·0012277
Steam	100	19·220 —	0·6240	0·0007611
Ice..........	100	23735·000 —	765·0000	0·9400000
Water......	100	25250·000 —	814·0000	1·0000000
Platinum .	100	542875·000 —	17512·0000	21·5000000

GREENSTONE is an intimate mixture of felspar and hornblende. See HONE SLATES.

GRINDING and POLISHING, two important processes in the useful arts, variously applied, one for the production of *form*, and the other for that of *surface*. In the production of form by cutting, the material is mostly removed in chips and fragments, which in the case of metal admit of being reunited

by fusion; but in the production of form by *abrasion*, of which grinding and polishing may be considered as the two extremes, the materials removed are ground to powder, and seldom admit of further application.

Most of the substances employed in the mechanical arts from the three kingdoms of nature admit of being ground and polished, by the application of certain abrasive surfaces or powders, applied by means of appropriate tools or apparatus. In some cases, the same substance may form the material to be polished, the polishing material, or the tool. For example, glass is ground and polished, as in plate-glass, cut-glass, and lenses; glass pulverised and glued upon paper is used as a polishing material; glass is also used as a tool or rubber, by means of which polishing powders are applied to metal works while being polished. So also with respect to iron, this metal is ground and polished in various forms; it is also used in the form of a disc or *skive*, with diamond powder, as a lap for polishing diamonds for jewellery; in the form of peroxide, or *crocus*, it is used for many purposes, such as polishing the specula of reflecting telescopes.

The grinding and polishing materials used in the arts, principally consist of *carbon*, as in the *diamond*, and compounds of alumina and silex in various degrees of crystallization and admixture, and usually combined with oxide of iron or lime; such are *sapphire*, *ruby*, *corundum*, *emery* and *rotten-stone; flint*, *tripoli*, *polishing-slate*, *Bohemian-stone*, *Turkey-stone*, and *pumice-stone: oxide of iron*, *oxide of tin*, and *chalk*, are also used as polishing powders.

Some abrasive substances are used in the solid form, as the *grind-stone*, *oil-stone*, *hones*, *charcoal*, *Dutch-rush*, and *fish-skin;* a few are pulverised and mixed with various cements, as the grindstone and razor-hone of the Hindoo (described under EMERY, page 596); crocus mixed with wax is also used by our opticians. But the polishing powders having been separated into grains of similar magnitude (as described in EMERY), are usually applied by means of metal, wood, paper, leather, cloth, or bristles, proceeding gradually from the coarser to the finer powder, as the form of the work becomes gradually developed. The grinding powder is of course harder than the substance to be ground, but the implement or grinding tool is softer, and generally agrees in form with the analogous cutting or moulding tools used for producing work of corresponding shapes in other substances. Thus turned works are often polished with wooden tools, applied with the powders; flat works require factitious saws, files, and planes; a convex surface requires a concave grinding tool, and so on.

Great care must be taken in polishing to prevent the different powders and materials from becoming mixed. A grain or two of a coarse powder mixed with the fine, would produce deep scratches, and entirely nullify the effects produced by the powders of intermediate degrees of fineness. Hence, great cleanliness is required on the part of the operator, and between every two stages of polishing, there ought to be a careful rinsing of the work with water, and the entire removal of the previous materials used.

For special details respecting grinding and polishing, we must refer to separate articles. The grinding and polishing of Earl Rosse's specula are described under CASTING AND FOUNDING, p. 349. See also GLASS — LENS — EMERY — CUTLERY — MARBLE — LAPIDARY WORK, &c.

GRINDSTONE. A large variety of sandstone grits are used in the arts for grinding articles into shape, or for giving them a smooth and polished surface. They are formed into flat circular stones, called grindstones, of different diameters and thickness, and made to revolve with different degrees of velocity. When not in constant use, they are commonly turned by winch handles; but at Sheffield, Birmingham, and other places, where they are in constant use, they are mounted in large grind or blade-mills, and are turned by straps acting on their axles, the moving power being either water or steam. [See CUTLERY.] The following are a few of the substances used for the grindstones in common use: 1. *Newcastle grindstones*, from the coal districts of Northumberland, Durham, Yorkshire, and Derbyshire, are selected of different degrees of density and coarseness, for the various manufactures of Sheffield and Birmingham. 2. *Bilston grindstone* is similar to No. 1, but of a lighter colour, much finer, very sharp, but not too hard. It is confined to a small spot of limited extent and thickness, near Bilston, in Staffordshire, where it lies above the coal, and is quarried entirely for the purpose of grindstones. 3. *Carpenter's rubstone* is a hard, close variety, used as a portable stone for sharpening tools by rubbing them on the flat stone instead of grinding. It is also used for giving a smooth and uniform surface to copper plates for the engraver. A much softer variety of sandstone is usually cut into a square form, from 8 to 12 inches long, in which form they are used dry by shoemakers, pocket-book makers, cork cutters, and others, for giving a rough edge to thin-bladed knives, &c. 4. *Devonshire batts*, a porous, fine-grained sandstone, in considerable repute, from the quarries of Black Down Cliffs, near Collumpton. 5. *Yorkshire grit* is used as a polisher of marble, and of copper plates for engravers. 6. *Congleton grit*, a similar, but softer stone, and similarly applied. 7. *Sheffield grindstone* is a hard coarse grit used for grinding large files, &c.; it is obtained from Hardsley, about 14 miles north of Sheffield. 8. *Wickersley grindstones*, from Wickersley, about 9 miles east of Sheffield, are used for most purposes of grinding, as knives, scissors, razors, saws, and edge tools. 9. *Sheffield bluestone* has a finer grain than No. 7 or No. 8, and is used at Sheffield for finishing the grinding of articles of cutlery that have been prepared on No. 8. The bluestones are found in abundance on the north and south sides of Sheffield. Grinding on a bluestone is called *whittening*. See HONE-SLATES, and also Mr. Knight's paper in the Transactions of the Society of Arts, vol. 1.

GRIT. A variety of sandstone to which distinctive terms are applied in particular districts, as *mill-*

stone grit, red grit, white grit, grindstone grit, &c. In the North of England, the term *freestone* is applied to such gritstones as will work easily, and with a good face: *calliard stones* are intractable, close grained, almost flinty grits; *hazel* is applied to some hard grits in Aldstone Moor, Cumberland; at Newcastle, the word *post* signifies a *bed*, and is generally associated with gritstone rocks. The *calcareous grit* of Geology, is part of the middle oolite formation. *Millstone grit* contains beds of quartz pebbles, and is a coarse irregularly laminated rock.

GROATS, or GRITS,[1] oats decorticated or deprived of their husks, and used to form a decoction with water, called water-gruel. When bruised ready for use, they are called *Embden grits*, or *prepared*, or *patent grits*. When taken as an article of nourishment, a larger quantity of grits should be used than when required as a demulcent or diluent to promote perspiration in the early stage of a cold; in the latter case, the addition of butter, spices, wine, &c. must be avoided, and only a little sugar or salt used.

GROINS, the lines formed by the intersection of arched vaultings. Such intersections are called *groinings*, and the vaultings *groined arches*. They appear to have originated in the accidental intersection of arches, and afterwards to have formed the basis of an extensive system of decoration, as exhibited in the ceilings of many of our ecclesiastical structures. Groined arches are constructed with stone, brick, wood, and plaster. With the first two materials, a centering of wood is used to turn the arch, and form its groins. "The centering consists of several ribs dispersed at 3 or 4 feet distance, made to the size of the vault which has the greatest opening. The extremities of these ribs rest on beams supported by standards, and are boarded over without any regard to the transverse openings, which are afterwards formed by another set of ribs adapted thereto, and then boarded so as to meet the boarding of the first vault, which, if of considerable breadth, must have short ribs fixed upon its surface, in order to shorten the bearing of the boarding of the transverse opening; and thus the centering will be completed. . . . It is obvious, that in forming the ribs for each vault, the outer curve must be the arc of a circle, or ellipsis, within the curve of the vault, and distanced from it towards the axis equal to the thickness of the boarding. In making the groined centre, it will be necessary to find the place of the angles on the boarding of the large vault, in order to ascertain the place of the ribs and boarding of the transverse vault. This may be done by three different methods. First, let two straight edges be placed vertically at the angles, and a third straight edge, or an extended line, be made to touch the surface of the boarding, and marked at all the points of contact, keeping the latter straight edge or line always upon the edges of the two vertical straight edges. The defect of this method is, that the place of the angles at the bottom can never be found, since it would require the cross straight edge or line to be of infinite length, and the vertical ones of infinite height. A more eligible method therefore, where there is room, is, secondly, to fix two ribs in the transverse part, and direct a level straight edge upon their edges, so that the end may come in contact with the boards, and mark the boarding in this place; find a sufficient number of points for the purpose in the same manner, and draw curves through the points, which will give the curves for fixing the end of the filling-in ribs, otherwise called *jack-ribs*. In constructing groins to be finished with plaster, the angle must be first fixed, then straight longitudinal pieces parallel to the axis of the groin fixed, either flush with the under side of the angle ribs, or their under sides a little below those of the angle ribs, so as to admit of their being nailed together; this is the most eligible method of constructing plaster groins."[2] [See BRICKLAYING.]

GUDGEONS are the ends or extremities of a horizontal shaft which runs in the collar; they are made as small as possible consistently with their strength. The cube root of the weight of a water-wheel in hundredweights is found to be nearly equal to the diameter in inches of a cast-iron gudgeon strong enough to support it. Gudgeons of cast and of wrought iron are in the proportions of 9 to 14. Those parts of a shaft which revolve between the points where the power and resistance are applied, are called *journals*, and the diameter of these as well as of gudgeons serves in some degree to proportion the shaft. The axis of the gudgeon should always be in the line with the axis of the shaft. When water-wheels are of timber, their diameter in feet, multiplied by the width in feet, plus the square of half the diameter, will give a sum, the cube root of which is the diameter of the gudgeon in inches. Spindles to grindstones, or to other wheels, may be calculated in the same manner.

GUM. A term applied to several modifications of a distinct proximate principle of vegetables, of more universal occurrence than any other secretion by plants. Some of these modifications are termed *mucilage*.[3] In fact, gum is the material usually prepared by plants for their own nutrition; in which state it is in solution; but when the bark is wounded either by the knife, by the puncture of insects, by disease, or by means of certain fungi, the solution escapes to the surface, thickens, and even becomes solid and pulverizable. The gums are characterised by forming a viscid, adhesive, or mucilaginous solution with water, and by being insoluble in alcohol; so that the addition of spirits of wine to a moderately strong aqueous solution of gum causes the separation of a white precipitate or magma, in consequence of the achohol combining with the water, and the gum,

(1) The word *grit* is usually applied to small particles of stone, or hard dirt; thus, *sandstone grit* consists of small siliceous particles; but as applied to shelled oats, the word appears to be derived from the dropping of the *s* in *grist*, which is corn or grain bruised or crushed.

(2) Nicholson's Architectural Dictionary.

(3) When certain seeds or roots are infused in water at 160° or 180°, subjected to pressure in a linen strainer, and the liquor evaporated, the residue resembles gum. Bruised linseed treated in this manner may be made to yield a substance closely resembling Gum Arabic.

having nothing to hold it in suspension, falls down. Another characteristic of gum is its convertibility into mucic or saclactic acid by the action of nitric acid.

There are two leading modifications of gum, one of which is represented by *Gum-Arabic*, and the other by *Gum-Tragacanth;* there are many intermediate varieties, amongst which *Cherry-tree Gum* may be distinguished: the different kinds of gums have been classed under the generic terms of *Arabine, Tragacanthine,* and *Cerasine,* (from *cerasus,* a cherry-tree.)

GUM-ARABIC is the produce of several species of acacia growing in Arabia, India, Upper Egypt, Senegal, &c. It occurs in rounded pieces, or *tears,* and in fragments, up to the size of a walnut, or larger: these are of irregular shape: the colour is either white, yellowish, or dark wine yellow; there is scarcely any odour, and the taste is mawkish and glutinous; the sp. gr. varies from 1·30 to 1·50. It breaks readily into small irregular pieces, with an uneven vitreous fracture. It dissolves almost completely in water; 100 parts of water at 212° Fahr. take up 19 parts of gum. The solution is, however, purer when made with cold water, and keeps better: it is sometimes used as a glaze or varnish, and for the purpose of giving a gloss and stiffness to ribands, calico, &c. The sp. gr. of the solution being greater than that of water, many substances in a state of minute mechanical division which will subside in water, will not do so in mucilage: hence the use of gum in writing ink and in some paints, and in the pigments used in calico-printing, &c. When gum is sold in powder, it is often adulterated with starch, the presence of which may be detected by tincture of iodine, which strikes a blue colour; or when cold water is used for the solution, the starch remains undissolved. Gum is highly nutritive, and is used in medicine as a demulcent.

At an average of the 3 years ending 1842, the gum-Arabic entered for consumption in the United Kingdom amounted to 18,176 cwts. a-year. *Gum-Senegal,* from the island of that name on the coast of Africa, is largely used by the calico-printers intead of gum-Arabic.

GUM-TRAGACANTH is the produce of certain species of *Astragalus,* growing in Asia Minor, Armenia, and Northern Persia. It is usually in the form of white or yellowish semi-transparent flakes, or curled vermicular pieces, which are very tough, and require, before they can be powdered, to be dried at 212°, when they lose about 10 per cent. of water, and become brittle. When steeped in water this gum swells into a bulky mucilaginous mass, which, when boiled with water, gradually acquires the appearance of a solution of ordinary gum. 100 parts of tragacanth yield 53 of arabine and 33 of tragacanthine, or *bassorine,* a mucilaginous substance forming the bulk of *Gum Bassora,* the remainder being water and oxalate of lime. Gum-tragacanth is used for some of the purposes to which gum-Arabic is applied. It is often sold in the shops as *gum-dragon.*

CHERRY-TREE GUM, including that of peach and apricot-trees, and other species of *Prunus,* resembles inferior gum-Arabic in its external characters, but is only partially soluble in cold water. It differs from it in some of its chemical relations.

GUM-RESINS are vegetable secretions which are most abundantly and most perfectly produced in warm countries, from trees and shrubs of particular tribes of plants, but rarely from herbaceous plants, except the large herbaceous umbelliferæ, which yield the fœtid gum-resins. They either exude spontaneously, or from incisions made in the stem and branches. "When they first escape to the surface they are fluid, and of a light colour, but gradually harden and become of a deeper hue, either by the evaporation of some of their volatile oil, or by the absorption of oxygen from the air and the conversion of the oil into a resin. Some remain in a semi-liquid, viscid state, such as *sagapenum* and *galbanum,* which are only pulverizable in winter. Most gum-resins possess a strong odour, (which in many instances is disagreeable, such as that of *asafœtida,*) with a warm acrid taste, and by application to the skin for any considerable time, they cause redness and inflammation. Owing to their composition being a mixture of gum and resin, they are not completely soluble either in water or absolute alcohol, but are perfectly dissolved in proof spirit, which is much employed to prepare tinctures of this class of substances. The gum, being soluble in water, is capable for a time of holding the resinous portion suspended in water, thereby forming an emulsion, a state which admits of their administration, if used soon after being prepared; for by rest they separate. Many of them are soluble to a certain extent in acetic acid, especially when assisted by heat. The strong mineral acids char them, and produce chemical changes. Many gum-resins are popularly termed *balsams,* a designation to which they have no title, as they do not contain benzoic acid."

ARTIFICIAL GUM. In the processes of calico-printing and for stiffening different goods, an artificially prepared gum has for some years been employed. In the article BEER, page 112, it is stated, that starch or fecula is by the action of diastase, a peculiar azotised substance formed during the germination of seeds, converted into a gummy mucilaginous substance named *dextrine.* It is also known in commerce under the name of *British gum* and *torrefied starch.* The term *leiocome* has been applied by Payen to a modified dextrine, whiter and more soluble than can be obtained by torrefaction. It is formed by moistening 1,000 parts of dry starch (potato starch is generally used) with very dilute nitric acid, consisting of 2 parts of concentrated acid and 300 of water: the mixture is divided into small blocks, which, when dried in the air, are rubbed down and exposed in a proper drying-stove to a current of air heated to about 150° or 160°: the powder is afterwards well dried at a temperature not exceeding 230°. When well made it dissolves in cold or tepid water as easily as gum-Arabic.

From a recent paper by M. Emile Thomas, quoted

in the *Chemical Gazette*, it appears that artificial gum is manufactured in three distinct forms; viz. as a white, brilliant, pearly powder; as a syrupy solution; and in the form of exotic gum in greater or less perfection, either broken into small fragments, or made into rolls of various sizes.

Dextrine is manufactured either by the use of acids or by means of the diastase contained in malted barley. When sulphuric acid is used, the dextrine is deliquescent, and the products often coloured: hence this acid is not used. Pure nitric acid is commonly employed for obtaining dextrine in the state of powder, as in M. Payen's process. Muriatic acid is also used for rendering the starch soluble, and it is then dried at a high temperature. The powder thus obtained is thrown upon a metallic sieve, and submitted to the action of a jet of steam, which moistens the dextrine so as to render it transparent without liquefying it: after this it requires very little drying. This process, however, requires more skill than can be expected of an ordinary workman.

The process by diastase seems to be the most advantageous. The fecula is rendered soluble in vats heated by steam in such a manner that the temperature may be easily raised or lowered. The fecula is first mixed with 4 times its weight of water at about 122° Fahr. At one operation about 600 lbs. of fecula are mixed with 1,200 quarts of water. The temperature must be kept at about 140° until the whole mass is converted into starch; 2 per cent. by weight of very white malted barley is then added, and also the mucilage produced from 1 per cent. of linseed. If a larger proportion of malt were used, the decomposition would be more rapid, but a larger quantity of glucose would be formed, and the gum would be more coloured. The mucilage of linseed imparts tenacity to the gum. The mixture must be kept at about 120° or 140° until all the starch is again dissolved; the temperature should then be suddenly raised, taking care, however, not to exceed 167°, but keeping as near that temperature as can be in order to cause the diastase to act as powerfully as possible. The mixture is then to be well stirred until the decomposition is almost complete: this may be ascertained by testing with iodine, which ought to give a violet approaching to red, instead of the characteristic blue tint. During the decomposition the liquid must be kept constantly in motion: the operation lasts about an hour and a quarter; that is to say, a quarter of an hour for the formation of the paste, one for its dissolution, and the other three-quarters for rendering it soluble. The liquor is then removed from the decomposing vats, and left in pans to settle for from 6 to 18 hours, according to the external temperature. During this time a slight fermentation will be perceptible, but it must be checked by adding alum in the proportion of 10 grammes for every 25 gallons of liquid. By allowing this time for the mixture to settle, the colouring of the gum while being baked is avoided. When drawn off, the liquor will mark about 10° B: it is then evaporated by raising it very slowly to the boiling point, the perfect clarification being accelerated by checking the first boiling, as in refining sugar. This clarification is effected without any foreign agent, by the coagulation of the vegetable albumen contained in the malt and the linseed mucilage. The scum which rises to the top must be carefully removed. If the boiling be hastened, the gum will first become thick, and afterwards be coloured. When a solid pellicle of gum forms on the surface the baking will be completed, at which time the syrup will mark about 35° B. If the gum is to be kept in a liquid form, the baking must be stopped at 30° while boiling, and the syrup be poured into well-closed vessels, previously rubbed with oil of turpentine, and the surface of the gum be covered with a thin layer of that oil. This method is tolerably successful in preventing fermentation. When it is desired to solidify the gum, the boiling syrup is poured into small flat tin vessels, placed upon a hot-air stove, kept at a temperature of from 104° to 122°. At the end of 24 hours the gum will acquire the consistency of jujube-paste: it is then to be cut up with a pair of shears into small oblong pieces, and these are to be rolled out upon a polished table with a wooden roller, dusted with pulverized artificial gum, and afterwards placed upon wooden frames, and left for 3 or 4 days to dry. The artificial gum, thus prepared, dissolves easily, and makes a very clear solution.

GUN. Agreeing with the remark of Fenelon, in his "Telemaque," that to be always prepared for war is the surest way to avoid it, we must regard with interest the details respecting the manufacture of fire-arms. Large guns or cannon appear to have been used by Edward III. in his first campaign against the Scots in 1327. At the battle of Cressy, in 1346, they occasioned much terror and surprise in the enemy. Other accounts state that the French used cannon in 1338, and gunpowder at the siege of Algiers in 1342. In 1378 the English are said to have used 400 cannon at the siege of St. Malo, but these were probably hand-cannon or culverins. In 1418 we read of stones being used as shot, and these were often of very large size, being hooped together with iron rings in masses of 1,200 lbs. weight. As knowledge increased, its improving influence extended even to weapons of destruction: cannon were reduced in size, and cast in iron and bronze; and iron bullets were first used in England in 1550. Cannon continued to be cast in a very clumsy form for a great number of years, until it was proposed by Monk to remove a quantity of useless metal from before the trunnions, and increase the thickness considerably where alone it is required, viz. at the breech end. A 56-pounder cannon, cast on this plan, was tried at Deal in 1839. It was 11 feet long; the diameter of the bore was 7·6 inches; the weight 98 cwt.; the windage 0·175. At an elevation of 32°, with a cast-iron shell filled with lead, weighing $62\frac{1}{2}$ lbs. and 16 lbs. of powder, the range was 5,720 yards, or $3\frac{1}{4}$ miles, the greatest distance which had ever been attained by any projectile with any charge whatever, and the greatest velocity, the whole time of flight

being only $30\frac{1}{4}$ seconds, which is estimated at 2,100 feet in the first second. Guns on this plan are several hundredweight lighter than on the old one, and they recoil less. It was found, contrary to the received opinion, that by increasing the windage the range was increased; because in long guns, if the bullet fit the bore closely, and a great velocity be desired, the column of air to be displaced before the ball quits the gun is considerable, and is condensed so rapidly, that it offers immense resistance to the passage of the bullet; but by reducing the size of the ball, so as to increase the windage, the air has more space to rush round it and hence the ball escapes with greater facility.

The casting of large guns is noticed under CASTING AND FOUNDING, p. 344; and the boring of the same, under BORING, p. 163.

Hand-guns, or small fire-arms, appear to have been introduced in 1471, when Edward IV., landing at Ravenspur, in Yorkshire, brought with him, among other forces, 300 Flemings armed with hand-guns. After this they became common. At first they were fired by the application by hand of a lighted match to the touch-hole. This was improved by the invention of the *match-lock*, a contrivance suggested by the trigger of the cross-bow, to convey with certainty and instantaneous motion the burning match to the pan: hence the weapon was called *arquebus*, or *harquebus*. The match-lock was superseded by the *wheel-lock*, a small apparatus for exciting sparks of fire by the friction of a furrowed wheel of steel against a piece of sulphuret of iron, which, from such application, acquired the name of *pyrites*, or *fire-stone*. The fourth great improvement was the *flint-lock*, which continued from the time of Elizabeth to the present century, when the invention of the *percussion-lock* has superseded all other forms.

The essential accompaniment of the percussion-lock is the *percussion-cap*, an invention which passed through many stages of progression before it attained its present exquisite simplicity. The application also of a proper fulminating powder was long a matter of great difficulty. Fulminating mercury was found to be uncertain in its action, on account of the extreme rapidity of its combustion, passing through and scattering the gunpowder without igniting it, just as the discharge of a Leyden jar is known to do. But as gunpowder can be easily fired by electricity, if means be employed to retard the amazing velocity with which the fluid moves, such as making a piece of wet string form part of the line of discharge, so by mixing a more slowly burning substance with fulminating mercury, the desired effect is produced. For this purpose 6 parts of *pulverine*, or meal-gunpowder, with 10 parts of fulminating mercury, form a good composition for priming copper caps.

The introduction of percussion caps led also to the necessity of altering the breeching of guns. The breeching or plug of a gun was formerly a solid lump of iron screwed into the barrel close to one end, the touch-hole being drilled through the side of the barrel above it. Long before the introduction of percussion caps it was a matter of complaint that these guns fired very slowly, and that a considerable portion of the powder was blown out uninflamed, so that much force was lost. A great improvement was made by Nock, in 1787, who introduced a form of breeching, Fig. 1111, which caused the powder to be ignited in the centre: this method was found to be safer; it did not cause the gun to leak by long-continued use, it greatly improved the strength and regularity of shooting, and it prevented the gun from becoming partially foul. This breeching continued in use for fifty years without any real improvement, but when percussion caps came into use, there was a complaint that they did not shoot so strong as the old flint guns. This led to the invention of other forms of breeching, of which that by Mr. Wilkinson, Fig. 1112, has been approved.

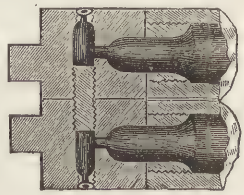


Fig. 1111.

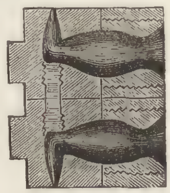


Fig. 1112.

The locks of guns have also passed through a great variety of changes. Indeed, as Mr. Wilkinson observes,[1] "there is probably no branch of the mechanic arts that has so much occupied the attention of persons unconnected with it professionally, as the improvement of fire-arms, either from its importance in a military point of view, or from the importance attached to its perfection by all sportsmen. The consequence has been, an inundation of alterations, few of which deserve the name of improvements; and they have been gradually or speedily forgotten, according to their comparative merits. One great error into which amateur improvers of fire-arms are very liable to fall, is their forgetfulness of the action of gunpowder on metals, particularly when exposed to the influence of a damp atmosphere. Many ingenious contrivances are annually produced, which, but for this circumstance, might continue to act perfectly well, and if the same mechanism were applicable to other purposes, would do credit to the inventors. Another error is that of making experiments on too diminutive a scale, and arguing that if successful with a pistol or a musket, the same plan will prove equally efficient with a cannon: nothing can be more fallacious, or more common. As these errors arise from a want of practical knowledge, I merely notice them in consequence of having been so often applied to, confidentially, for my opinion of inventions for which patents were about to be obtained; and I have frequently, in vain, attempted to convince the parties that success was absolutely impossible; for as parents feel greater affection for their own children than for those of others, so it is with projectors and their inventions. Few persons are aware of the immense force with which the flame rushes from the vent hole

(1) Engines of War; by Henry Wilkinson, M.R.A.S. London; 1841.

of a large cannon when loaded with its service charge. An experiment made at Woolwich affords a striking illustration of the fact: a cannon ball weighing 24lbs. was placed exactly over the vent hole of a loaded 32-pounder cannon, which was fired by a train of gunpowder, when the rush from the vent projected the 24-pounder ball to a very considerable height in the air, although the diameter of the hole was only $\frac{2}{10}$ inch. This is one of the causes which renders the application of the percussion system to cannon more difficult than might at the first glance be imagined; and, in order to prove the necessity of making all experiments in gunnery on as large a scale as it is ever intended to apply to the same principle, I will illustrate it by a failure of my own. Conceiving that this difficulty would be overcome if the cock struck round the vent hole, leaving a large conical space in the centre for the escape of the flame, I constructed a cannon-lock on this principle, which was tried on board the *Excellent* at Portsmouth, and found to succeed perfectly with 12-pounders, and even with 24-pounders not shotted; but when fully charged, the lock was broken. I have since constructed a very cheap and simple one, which answers perfectly."

The manufacture of a gun is rather a complicated affair; but we will endeavour, with the assistance of Mr. Wilkinson's well-written little volume, Mr. Greener's two excellent works,[1] and our own observations in the workshops of Birmingham, to convey a concise but adequate description of the same; we shall, however, confine our notice chiefly to the best made guns, which are for the most part finished in London, the separate parts being supplied in the rough from the country. The muskets and cheap guns manufactured at Birmingham go through the same processes as the best guns, but fewer hands are concerned in the manufacture, and less care is bestowed upon them.

Every best-finished gun usually passes through 15 or 16 hands, each of which represents almost a distinct trade. They may be arranged in the following order:—1, Barrel-forger; 2, lock and furniture forger; 3, barrel borer and filer; 4, lock filer; 5, furniture filer; 6, ribber and breecher; 7, stocker; 8, screwer-together; 9, detonator; 10, maker-off; 11, stripper and finisher; 12, lock finisher; 13, polisher and hardener; 14, engraver; 15, browner; 16, stock polisher.

Forging.—The forging of gun-barrels varies according to the quality intended to be produced, or the use to which the barrels are to be applied. Musket or common barrels were formerly made from what are called *skelps.* The skelp is a piece of iron about 3 feet long and 4 inches wide, but thicker and broader at one end than at the other; and the barrel was formed by forging out such pieces to the proper dimensions, and then folding or bending them round into a cylindrical form until the edges overlapped, so that they could be welded together. Mr. Babbage, in his "Economy of Manufactures," informs us how these methods of forging and welding came to be abandoned. Some years ago, the men employed in an extensive factory in forging these skelps, struck for higher wages, and their demands being exorbitant were not complied with. While the dispute was pending, it occurred to the superintendent that if the circumference of the rollers between which the bar iron was rolled were to be made equal to the length of a skelp or of a musket-barrel, and if the grooves in which the iron was compressed, instead of being equally deep and wide, were cut gradually deeper and wider from a point in the rollers until it returned to the same point, then the bar iron passing between such rollers, instead of being uniform in width and thickness, would have the form of a skelp. The plan was perfectly successful, and the services of the refractory skelp-forgers were no longer required. Such is the moral to be read from the history of every strike; but so difficult is it for us to profit by the experience of others, that this severe lesson was lost upon the skelp-welders. A contract having been entered into for a considerable supply of gun-barrels to be delivered on a fixed day, the men struck for such an advance of wages as would have caused the completion of the contract to be attended with a heavy loss. Under these circumstances of difficulty, the contractor turned his attention to the perfecting of a process which some years before had been patented for welding gun-barrels by rollers. The plan was so successful that it greatly surpassed the results of hand labour. The process consisted in turning a bar of iron about a foot long into the form of a cylinder with the edges a little overlapping. It was then raised to a welding heat, and a triblet or cylinder of iron being placed in it, it was passed quickly through a pair of rollers. The welding was thus performed at a single heating, and the remainder of the elongation necessary to bring it to the length of a musket-barrel was performed in a similar manner, but at a lower temperature. This invention broke up the combination, and brought in a class of men at considerably lower wages. After this, there was no hope that the skelp-welders could ever recover the position they had forfeited; for not only was the work done better and cheaper, but the new method was found to be less injurious to the texture of the iron, which was now exposed only once instead of three or four times to the welding heat. The new process was also found to be adapted to the manufacture of iron tubes for the conveyance of gas or of water for warming houses.

Barrels for fowling-pieces are known as *stub, stub-twist, wire-twist, Damascus-twist,* or the two latter combined; also *stub-Damascus.* There are also a variety of inferior kinds, which do not require notice.

Stub-iron is formed from old horse-shoe nails, called *stubs;* this form of iron being preferred on account of its excellence obtained by repeated workings; for if the iron were bad, the nails could not be driven into the horse's hoof. The stubs are packed closely

(1) "The Gun, or a treatise on the various descriptions of small fire-arms;" by William Greener. 1835.

"The Science of Gunnery, as applied to the construction of fire-arms;" by the same. 1841.

together, bound with an iron hoop into a ball 10 or 12 inches in circumference, raised to a welding heat, united by hammering, and then drawn out into bars of convenient length. This method is adopted for the locks, furniture, and breechings, of the best guns, and also, to some extent, for barrels. The quantity of nails that can be obtained in this country is not adequate to the demand, so that immense numbers are imported from France, Holland, Sweden, and other parts, in casks, containing from 16 to 18 cwt. each. For the manufacture of gun-barrels they are sorted and picked, to separate cast-iron and impurities, and about half a cwt. are then put into a large cast-iron drum, crossed internally with iron bars, through the centre of which a shaft passes, which is connected by a strap with the steam-engine, and the revolution of the driver polishes the nails by their friction against each other: the dust is then separated by sifting. The stubs alone would produce too soft a metal: a portion of steel is therefore mixed with them, varying from $\frac{1}{8}$ to $\frac{1}{2}$ of the whole mass. The steel is clipped into pieces corresponding in size with the stubs. About 40 lbs. are then thrown on the hearth of an iron-furnace, and they are puddled or mixed together with a long iron rod, and the bloom thus formed is welded under a hammer of 3 tons weight, to a long square block; this is then raised to a bright red heat, and drawn out under a tilt hammer into bars of the proper size to pass the rollers, by which it is reduced to rods of the required size. The iron thus produced is very tough, and free from specks or *greys*.

Stub-barrels are also made from *scrap*-iron, which consists of the cuttings from various manufactories, the cuttings and punchings of sheet-iron, as well as worn-out articles in iron. These are sorted and used in preparing iron of various qualities, known as *wire*-twist, *Damascus*-twist, *stub*-twist, *charcoal*-iron, *three-penny skelp*-iron, *twopenny*, or *Wednesbury-skelp*, *sham-damn-skelp*, &c. The scrap is cut into small pieces, the object being to cross and interweave the fibres in every possible direction, and thus to increase its tenacity. For the finest description of barrels, a certain proportion of scrap-steel, such as broken coach-springs, is cut into pieces and puddled in with the iron, whereby the steel loses much of its carbon and becomes converted into *mild* steel; it unites readily with the iron, and improves the variegation and beauty of the twist. For *twisted* barrels the iron is drawn out into ribands by rolling into lengths of several yards, and about $\frac{1}{2}$ inch wide, varying in thickness according to the part of the barrel to which the ribbons are to be applied. They are cut into lengths, each sufficient to form one-third of the barrel. One of these lengths is made red-hot and twisted into a spiral form, by placing one end in the prong of an iron rod, Fig. 1113, which passes through a frame, and is turned by a handle, the riband being prevented from going round without twisting, by means of an iron bar placed parallel to the revolving rod. The spiral thus formed is raised to a welding-heat, and dropped upon an iron cylindrical rod, which, being struck forcibly on the ground, (called *jumping*,) the edges of the spiral unite and the welding is completed by hammering on the anvil. The other spirals are added to complete the length of the barrel, and the forging is finished by hammering regularly all over. *Wire*-twist, of any degree of fineness, is obtained by welding alternate laminæ of iron and steel, or iron of two qualities together, and drawing the compound bar into ribands as before. The beauty of the barrel is increased by twisting, and also its strength, because the longitudinal direction of the fibres is thus opposed to the expansion that takes place in firing. *Damascus* iron, so called from its resemblance to the celebrated Oriental barrels and sword blades, is produced in various ways. "One method is to unite by welding 25 bars of iron and mild steel alternately, each about 2 feet long, 2 inches wide, and $\frac{1}{4}$ inch thick, and having drawn the whole into a long bar or rod, $\frac{5}{8}$ inch square, it is then cut into lengths of 5 or 6 feet. One of these pieces, being heated to redness, is held firmly in a vice to prevent it from turning, while the other end is twisted by a brace or by machinery, taking care that the turns are regular, and holding those parts which turn closer than the other with a pair of tongs: the rod is thus shortened to half its original length, and made quite cylindrical. If only two pieces are employed to form the riband, one is turned to the right and the other to the left; these being laid parallel to each other, are united by welding and then flattened; but if 3 square rods are used, the centre one is turned in a contrary direction to the outside ones, and this produces the handsomest figure. By these operations the alternations of iron and steel change places at every half revolution of the square rod, composed of 25 laminæ, the external layers winding round the interior ones, thus forming, when flattened into a riband, irregular concentric ovals or circles. The fineness of the Damascus depends on the number and thickness of the alternations; and the figure of the riband, when brought out by acids, resembles that of a curled ostrich feather; but when wound into a spiral form, and united on its edge by jumping, the edges bend round and the figure is completed." A thin riband of Damascus is sometimes veneered on common iron or gas tubing, so as to form gun-barrels of a very low price with a high-priced appearance. *Stub-Damascus* is only one square rod of Damascus iron twisted and flattened into the riband for forming the barrel. *Damascus and wire-twist* is a riband of each twisted together.

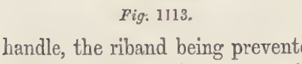


Fig. 1113.

Boring and grinding.—The barrel being forged, the next operation is boring, which is usually done by machinery. A long square bit, attached to a rod, is made to revolve rapidly while the barrel is pressed forwards by a crooked lever, held at one end by the workman while he passes the other along a series of pegs driven into the top edge of the trough or bench on which the barrel is placed, thus forcing the barrel

forward along the boring-bit. The barrel is kept cool by water flowing constantly over it, otherwise the heat generated would destroy the bit. The outsides are then ground on very broad stones; for which purpose the man sits on a kind of wooden horse chained to the floor, and leans with the barrel against a sloping board nearly in contact with the grindstone; a long iron rod, passed through the barrel, projects at each end, and forms handles and also an axis on which the barrel rotates, more or less freely, according to the degree of pressure against the board. By moving it regularly sideways, the whole surface is ground over, and although the stones are well supplied with water, the sparks fly off with the brilliancy of fire-works. Many barrels, after being smoothed up, are finished in this way, the appearance of regularity being given to them at the muzzle by filing. The best barrels, however, are first set perfectly straight, then fixed on a movable carriage, which is drawn gradually forward along a level surface or railway, by means of a weight and pulleys, the boring-bit being fixed in a square hole in the axis of a revolving fly-wheel, while the barrel slowly advances until the bit passes out at the opposite end to that at which it entered. The same square bit is used to enlarge the bore to the required size by the addition of a spill, or long thin piece of wood, slightly taper, flat on one side and round on the other: this being placed along one side of the bit causes it to cut on two angles only, and the size of the calibre may be very gradually increased by interposing strips of writing-paper between the spill and the bit. Mr. Wilkinson states that "the best and most usual form for the inside of a barrel intended to throw shot, is a cylinder slightly relieved, or enlarged a few inches at the breech end: long barrels for duck-shooting should be eased gradually towards the muzzle end also. It is evident, that a barrel much opened behind must recoil more, and *lead* sooner, than one approaching nearer to a cylinder; and if resistance be necessary, it should be given to the powder, and not to the shot, which is accomplished by the elliptical form of breeching." When the barrel has been correctly bored, the external part is turned in a lathe, a steel mandril is introduced at each end, and the superfluous metal taken off by hand or by a slide rest. The barrel being rendered perfectly correct and equal in every part, is *tapped* or screwed at the breech end, and the plug fitted. It is next proved according to a scale fixed by Act of Parliament, with a charge of powder proportioned to the weight of a leaden ball that fits the bore.

The proving of guns is a very necessary precaution, to prevent, as far as possible, fraudulent makers from sending into the market barrels made of bad or unsound materials. In 1813, the Company of Gunmakers of the City of London instituted a proof-house, and obtained an Act of Incorporation: in 1815, further powers were granted to them, by which parties receiving any barrel to rib, stock, &c. without its having been first proved and stamped, are liable to a penalty of 20*l*., or not less than 20*s*. A similar establishment was also instituted at Birmingham, of which the following notice, with a few additional particulars, is from the second volume of the Editor's work on the "Useful Arts and Manufactures of Great Britain:"—

The Birmingham Company has also its Act of Incorporation, and wardens and a proof-master are appointed chiefly from among the gunmakers themselves, who are authorized to stamp on the guns proved by them the royal arms, with the letters B. P. V., that is, Birmingham Proof Viewed. The barrels of guns intended for the public service are proved at a separate establishment maintained entirely by the Government.

The Birmingham Proof-house is situated in Banbury-street, in the south-east division of the town. The building is somewhat extensive, and is separated into several distinct compartments. Within an inner court-yard is the gunpowder magazine, a small but massive stone building standing by itself: beyond this is a room for casting bullets; they are cast in long moulds formed of two parts, containing, when closed, a series of hollow spheres connected by a long channel, along which the melted lead flows, and shorter channels into each sphere, so that the bullets are turned out in the form shown in Fig. 1114, and are

Fig. 1114.

separated from the pipe and stems by a pair of nippers, with cutting edges, adapted to the surface of the bullet. Another department is appropriated to loading the barrels with powder and ball. The charge is regulated according to the weight and calibre of the barrel, a scale of printed regulations for the purpose being fixed up in the room. A measure filled with the gunpowder, containing three or four times the quantity which the barrel will afterwards have to bear, is poured in by means of a funnel, and well rammed down with a heavy copper ramrod; then the bullet, which exactly fits the barrel, is driven home, no wadding being used. A number of barrels being thus prepared, are taken to the firing-house, which is a low detached shed, lined throughout with thick sheet iron, and furnished with openings on one side and in the roof, which are closed with iron louvres. Iron frames are laid the whole length of the room for the reception of the barrels, to the number of 129, in two rows, one above the other. They are placed about 6 inches apart, and point to the opposite dead wall, against which is a mass of sand for receiving the balls. Behind the frame on which the twist barrels are fixed, is another mass of sand, in which, on the recoil, the barrels become buried. Behind the frame on which the common barrels and muskets are tried, a strong iron bar is placed, to receive the tang of the breech, but not the barrel, and thus fixed, the barrels cannot fly back. A groove runs along the whole length of each frame for the train of powder, and upon this are laid the barrels with the touch-holes downwards. Matters being thus arranged, the shutters are closed, the

doors locked, and a man with a long rod heated at one end fires the train through a hole in one of the end walls left for the purpose. The noise of the explosion is very remarkable, forming as it does a rapid succession of loud sharp reports, lasting a second or two, and resembling the rattle of thunder. This is easily to be accounted for; for however rapid may be the explosion of gunpowder, the fire has to travel the whole length of the train, in order to fire the guns; the time occupied herein occasions each gun to give a distinct report, which, being instantly followed by the report of the next gun, produces the rattle or continuous peal referred to. The explosion being ended, a few minutes are allowed to elapse before the men enter to remove the guns, because a barrel occasionally *hangs fire,* and may explode in the act of being removed. The shutters being thrown up, and the doors opened, the smoke rushes out in clouds, and the appearance of the barrels is not a little extraordinary. It is scarcely to be supposed that in so large a number some should not be faulty; the defects are so well known as to obtain for them their appropriate names. A few may have a *chink* or small rent in the direction of the length of the barrel; others may have a *crack* across it; while others again may have a *flaw,* which is a small pit or hollow in the metal. In any one of these cases the barrel is likely to burst in proving, and is whirled out of the frame to a distant part of the shed. The editor has collected some of the forms of the burst barrels in the following sketches. In examining a large number

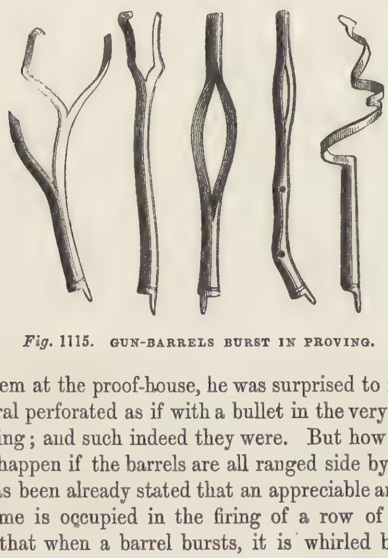


Fig. 1115. GUN-BARRELS BURST IN PROVING.

of them at the proof-house, he was surprised to notice several perforated as if with a bullet in the very act of proving; and such indeed they were. But how could this happen if the barrels are all ranged side by side? It has been already stated that an appreciable amount of time is occupied in the firing of a row of guns, and that when a barrel bursts, it is whirled by the force of the expanding gases out of its frame to a distant part of the shed. Now let us suppose that sixty barrels are arranged in one row, and fired by a train, and that the fifth in the row should burst, and be whirled out of its frame; in its passage to a distant part of the shed, it may meet the shot of one of the guns in advance of the position which it occupied in the row, in the very act of firing; such, for example, as the fortieth or fiftieth gun; and as this shot is urged by a triple or quadruple charge of powder, it would easily pass through the metal if it struck it favourably.

It rarely happens the best barrels burst: they are more frequently bulged or swelled out in places which are faulty, or of softer temper. The perfect barrels are marked with punches of different sizes, (but all bearing the same impression,) according to the quality of the barrel. At the London Proof-house, an additional punch is used, containing the number of the bore the barrel has been tried by, so that it can easily be ascertained whether the barrel has had any considerable quantity bored out after proving. The bulged-out barrels are sent back to the maker, who beats down the swellings, and sends back the barrel to be proved again. It will generally stand the second proof; but Mr. Greener has known four proofs of the same barrel to have been made. The common barrels are left untouched for four-and-twenty hours, when, if not burst, any holes or other imperfections are made quite apparent by the action of the saltpetre: such are sent back to the maker unmarked, but the sound barrels are washed out in a trough with warm water, and dried with tow. The viewer then carefully examines them, and hands such as are sound to the stamper, who attaches the proof-mark.

At the Government Proof-house at the time of the writer's visit, some barrels were being charged with 16 drachms of powder (only 4½ drachms being required for the gun in ordinary service); a wine-cork exactly fitting the barrel was then rammed down tight with a massive copper rod; the bullet was then put in, and another cork rammed upon that. Then each barrel was proved separately; for which purpose it was placed in a massive wooden chest, one end of which was left open for the escape of the bullet, which was fired as before into a pile of earth and sand. On closing the cover of this chest (which was nearly balanced by weights passing over a pulley), a spring was detached, which fired a percussion-cap and exploded the gun. In case of fracture, the chest protects the man from injury.

In some cases, the barrels are subjected to even a more severe test than either of the above. The barrel is filled with water, and an air-tight bullet driven in. Water being nearly incompressible, but transmitting pressure in all directions, insinuates itself into the minutest chink or crack, and appears on the outside, thus showing where the barrel is defective.

When false breeched, ribbed, stocked, and screwed together, the barrel is bored for shooting, and smoothed outside. Double barrels have a flat struck along the inner side of each before laying them together; about 4 inches of the breech end is braized or hard-soldered, the remainder of the length soft-soldered, the upper and under ribs being soldered on at the same time.

The lock and the barrel being jointed to each other if required, are given to the stocker, who lets them into the wood, which ought to be perfectly seasoned.

The screwer-together lets in all the furniture, and

puts in all the screws. The gun is detonated by another man, who fits the cock, and finishes the external part of the breeching. When the barrel has been smoothed and bored for shooting, the gun is returned to the screwer-together, or to another workman to *make off* and chequer; that is, to smooth and finish the wood-work. From him it passes to the *skipper* and *finisher*, who takes the whole to pieces, and corrects any trifling errors of the preceding workmen. The barrel is engraved and goes into brown; an operation performed by producing successive coatings of rust on the surface, and brushing them off as they arise with a fine steel wire *scratch-brush*, until the required colour is produced. This usually takes a week, and is effected by a solution of salts combined with nitric ether.[1] During this process, the lock and furniture are polished, engraved, blued, and hardened; and the stock is oiled and polished. The hardening is performed by burying the parts in animal charcoal, and keeping them at a red heat for an hour or more, and then plunging the whole into water. The whole of the parts are then returned to the finisher, and the gun is completed.

The stocks of all military fire-arms and most fowling-pieces are of walnut, which is the toughest and best wood for the purpose; but maple and ash are also used for sporting guns. All gun-stocks are coloured with cold-drawn linseed oil and alkanet root; and when sufficiently dry, those for the best guns are polished and varnished with shell-lac in spirits of wine, applied with a piece of rag, and when dry, rubbed down with fine pumice powder, and repeatedly varnished until all the pores of the wood are filled; and they are finally polished up with oil and rotten-stone, by hand.

Success in shooting depends a good deal on the proper adjustment of the stock to the stature of the shooter, or to his acquired habits. As a general rule, the taller a man is, the longer and more crooked ought to be his stock. The stock must also have an inclination outwards, to allow for the swell of the chest, as the eye cannot, without difficulty, be placed correctly in a line with the centre of the shoulder; hence, most persons shoot to the left of the object aimed at, particularly if the centre of the stock be in a right line with the barrel, or be *thrown off*, as it is called, the wrong way. The broader the chest, the more ought the stock to be inclined, or bent outwards sideways, and the extent is ascertained by observing the line of the barrel when the gun is thrown up to the shoulder at any distant fixed object.

Machinery for stocking military guns has been proposed and adopted to a considerable extent in France and America, and we have lately seen it applied in England.

The term *rifle* or *rifled* is applied to muskets or pieces of ordnance when their bores are furrowed with spiral grooves, the object of which will be understood from the following considerations. "A bullet made of lead cast in a spherical form, having unavoidably some irregularities on its surface, and from unequal expansion in cooling, a void space being formed in the interior, by which the density is caused to vary in different directions from the centre, it follows, that when such bullet is discharged from a common musket, the atmosphere pressing unequally against its front on opposite sides of the line of flight, causes it to deviate continually from the direction which, when uniformly resisted, it would take by gravity, and the impulse of the fired gunpowder. It will also happen that the bullet acquires by friction in the barrel a rotatory motion, about some diameter as an axis, and this diameter not coinciding, except by an extraordinary chance, with the proper path of the ball, the pressure of the air, which, when that coincidence does not take place, will be greater on the side of the ball where the revolving motion conspires with the direct motion, than on the opposite side, where the two motions are in contrary directions, will, even if there were no irregularity of surface, produce deviation. This will evidently be various, according to the position of the axis of rotation; and since that position may change during the flight of the ball, the path of the latter may suffer several inflections. The intention, therefore, of forming spiral grooves within the barrel, is to produce a rotatory motion of the shot about an axis which shall coincide with the line of its path, in order that the unequal pressure of the atmosphere in its front, on account of any irregularity in its form or density, may correct itself at every half revolution of the shot on such axis; so that, on arriving at the object, the deviation may be only that which is due to some fraction of a rotation. The number of spiral channels in a rifle musket has varied at different times; at first, there were 8 or 16, but the number was afterwards reduced to 4, and at present, the practice is to have but two. It has not been exactly determined what is the best form for the spiral; sometimes the curve-line makes in the length of the barrel 1¼ revolution about the axis of the latter, but in general, one revolution in the whole length (= 30 inches) is considered sufficient."[2]

GUN COTTON. Ordinary cotton is one of the innumerable forms of lignine, a compound of carbon, oxygen, and hydrogen; but by subjecting cotton to the action of nitric acid, another element enters into the composition, viz. nitrogen, which is found in nearly all explosive bodies. The action of nitric acid on vegetable matter had long attracted the attention of chemists before the discovery of the remarkable explosive compound which we are about to notice. In 1833 Braconnet gave an account in the *Annales de Chimie*, &c. of a new substance obtained by the action of concentrated nitric acid on starch, saw-dust, linen and cotton wool. He named this substance *xyloidine*, from ξύλον, *wood*, and described it as being white, pulverulent, neutral, and very inflammable. It

(1) Mr. Wilkinson gives the following recipe:—Nitric ether 6 oz., alcohol 1 oz., sulphate of copper 1½ oz., muriated tincture of iron 1½ oz., tincture of gum benzoin 1½ oz. The sulphate of copper must be dissolved in 3 pints of boiling water, and the other ingredients, previously mixed together, added.

(2) "Penny Cylopædia," art. Rifle.

is easily formed by boiling starch for a few moments in concentrated nitric acid until solution takes place; on pouring the solution into cold water, the xyloidine is precipitated, and may be collected and dried. In 1838 Pelouze, in the *Comptes Rendus*, called the attention of the Academy of Sciences to the properties of xyloidine, "which," he observes, "is very combustible, taking fire at 356° Fahr., burning with great rapidity and almost without residue. This property has led me to an experiment which I think susceptible of some applications, especially in artillery. By plunging paper in nitric acid of sp. gr. 1·5, leaving it there the requisite time for the acid to permeate the paper, which is usually accomplished in 2 or 3 minutes, then withdrawing it, and lastly, washing it in water, we obtain a kind of parchment impermeable to moisture, and extremely combustible." Dumas in the sixth vol. of his "Traité de Chimie appliquée aux Arts," published in 1843, proposed to name the compound *nitramidine*, and mentions the application of paper and pasteboard prepared by nitric acid for fireworks. At a meeting of the British Association at Southampton, in 1846, it was announced that Professor Schönbein had discovered a mode of rendering cotton so explosive as to form an excellent substitute for gunpowder. Specimens of the prepared cotton were exhibited, but the method of preparation was kept secret, as the inventor was then applying for a patent. Soon after this announcement Professor Otto, of Brunswick, published an account of an explosive cotton, as did also M. Morel, of Paris, and M. Böttger, of Frankfort. In April, 1847, Schönbein's patent was enrolled: the specification states that in preparing the cotton the patentee uses nitric acid of sp. gr. 1·45 to 1·50, and sulphuric acid of sp. gr. 1·85. These acids are to be mixed in the proportion of 3 parts of sulphuric and 1 part of nitric acid: the mixture is allowed to cool down to between 50° and 60° Fahr., and then rough cotton, free from all extraneous matter, is immersed in the liquid, in as open a state as possible, in a glazed earthenware vessel. When thoroughly soaked, the excess of acid is to be drawn or poured off and the cotton pressed lightly with an earthen presser to separate the principal part of the acid. The cotton is then covered over and left for an hour, then pressed, and well washed in running water, to get rid of all free acid: it is then to be partially dried by pressure, and to ensure its freedom from acid it is to be washed in a dilute solution of carbonate of potash, made by dissolving 1 oz. of this salt in a gallon of water: it is then put in a press, and the excess of alkaline solution pressed out, leaving the cotton nearly dry. It is next washed in a solution consisting of 1 oz. of pure nitrate of potash in 1 gallon of water, and when again pressed is dried in a room heated by steam or hot water to the temperature of from 150° to 170° Fahr. The nitrate of potash appears to increase the explosive force of the cotton, but it is not absolutely necessary. Of the cotton thus prepared 3 parts are said to be equal in force to 8 parts of Tower-proof gunpowder.

A simpler method of preparing gun cotton in small quantities was proposed by Mr. Thomas Taylor in October 1846:—"Mix in any convenient glass vessel an ounce and a half, by measure, of nitric acid, (sp. gr. 1·45 to 1·50,) with an equal quantity of sulphuric acid, (sp. gr. 1·80.) When the mixture has cooled, place 100 grains of fine cotton wool in a Wedgwood mortar, pour the acid over it, and with a glass rod imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely saturated, pour off the acid, and with the aid of a pestle, quickly squeeze out as much of the acid as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water or underneath a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water bath." Nitric acid of the sp. gr. 1·50 answers better than that of 1·45, the cotton being much less acted upon by the strong acid. Nitric acid of the sp. gr. 1·36 converts the cotton into a gelatinous mass.

Gun cotton is considerably heavier than unprepared cotton, and may be distinguished therefrom by its harshness, and by the crepitating sound produced when pressed by the hand. When well prepared, there is scarcely any change in colour or in general appearance. It may also be distinguished from common cotton by its electric condition, for if a portion be pulled briskly between the finger and thumb of a dry hand, the fibres will adhere to the hand with great tenacity. If a strip of prepared paper be thus treated, it will, on presenting one end to the knuckle, be alternately attracted and repelled, and thus part with its electricity. Gun cotton is also perfectly soluble in sulphuric ether, and if the solution be poured on the surface of cold water, the xyloidine forms an opaque film thereon, which when collected and dried forms a remarkable explosive paper. The etherial solution of gun cotton (named *collodium*) applied to a wound, coats it with a thin, delicate, artificial skin, which perfectly excludes the air.

The explosive character of gun cotton appears to be due to the formation of xyloidine in the tubes and upon the exterior of the cotton fibre under the action of the nitric acid. The sulphuric acid employed has no direct action on the lignine, its use being to abstract water, and thus render the action of the nitric acid more perfect. Gun cotton explodes with very great rapidity at from 350° to 400° Fahr. If a small heap of gunpowder be placed on a sheet of writing paper, and a bit of gun cotton be laid lightly upon it, and the whole held about a foot above the flame of a lamp or candle, the heat will soon be sufficient to ignite the cotton, but the powder will not be kindled, and although the cotton explodes in contact with the powder, its action is so rapid that there is not time enough to raise the gunpowder to the temperature required for its explosion. "This great rapidity of action is opposed to its utility for propulsive purposes. It is well known to practical men that a slowly exploding material is the best for artillery practice. Thus, when a slow powder is

used, the ball acquires a slight degree of motion, and puts the air in front of it in motion also, before the full power of the explosion is exerted; and that motion is gradually increased during the remainder of the explosion. But if the action takes place too quickly, the full force of the propelling power comes into play before the ball is in motion, and the bursting of the gun is the probable consequence. This is the reason why the fulminates of mercury and of silver have not been more extensively tried in warfare. When gun cotton has been carefully prepared, the products of its combustion are carbonic acid, watery vapour or steam, and free nitrogen. In some cases nitrous acid is produced, owing to defective washing, and when nitrate of potash has been employed, or, in fact, a solution of any solid salts, a dense white vapour accompanies the explosion. The quantity of water produced during the decomposition of the cotton by heat is so great, as to constitute an objection to its use in fire-arms. Its hygrometric condition also impedes its utility; for if a quantity be exposed for an hour or two to a damp atmosphere, it absorbs nearly its own weight of water, and requires re-drying before it can be used; it cannot be protected from atmospheric moisture by compression into cartridges, as in that state it does not explode with certainty. The idea of employing the fulminating cotton as a substitute for gunpowder for artillery purposes seems to be completely abandoned; but on account of the small quantity of smoke given off, as well as on account of its enormous force, it is much used for mining purposes; the proportionate quantity used being a fourth of that of powder."[1]

The expense of gun cotton is considerably greater than that of gunpowder, one reason for which is the difficulty and danger of manufacturing it in large quantities: it is also liable to spontaneous ignition or decomposition by keeping: Maurey describes a fearful spontaneous explosion of 1,600 kilogrammes of gun cotton, which had been washed with alkaline water. The explosion took place in his manufactory in July 1848, and he is not aware of any method of guarding against such accidents. Hence the use of gun cotton has been gradually abandoned in mining, and this substance, which a few years ago excited such great expectations, now scarcely occupies a rank higher than that of the curiosities of chemical science.

GUN FLINT. See FLINT.

GUNPOWDER. The Chinese appear to have been acquainted with gunpowder 200 years before the Christian era, if not earlier, and to have used it in their fire-works, and for purposes of deflagration, but not for detonation, or the propulsion of solid bodies. Such a compound as this is supposed to have been obtained by the Arabs, in their intercourse with China, and by them communicated to the Greeks of the Lower Empire, and to have formed the celebrated *Greek fire*, which enabled those who possessed the secret of its composition to gain so many victories; at any rate, the machines of war used by the Greeks at the period referred to are said to resemble those of the Chinese so closely as to lead to the suspicion of a common origin. Various recipes for deflagrating compounds are given by Marcus Græcus in his "Liber Ignium ad Comburendos Hostes," but no more precise date than between the 9th and 12th centuries has been assigned to this composition.[2] The crusaders in their early conflicts appear to have been struck with terror at the incendiary weapons used against them; and it has been conjectured, that to them do we owe the introduction of a form of gunpowder into Europe. It is probable that the impurity of the saltpetre and the imperfect method of mixing the ingredients, prevented the Chinese, Arabs and Greeks, from using gunpowder as a propelling force, and that the same proportions of saltpetre, charcoal, and sulphur, which give us a detonating compound, gave them only a deflagrating one. The alchemists may so far have supplied these defects as to have earned for them the merit of the invention. Such may have been the case with Berthold Schwartz, a Franciscan friar, who lived at Mayence between 1290 and 1320, whom the Germans claim as the inventor of gunpowder.

Referring the historical portion of our subject, which is beset with difficulties, to those who are competent to discuss it,[3] we would call attention for a moment to the great importance of the discovery of gunpowder, in assisting the progress of civilization. Its first effect was to change entirely the whole system of warfare, whether offensive or defensive: the feudal lord, who could no longer feel secure in his stronghold, which the cannon planted on the adjacent heights might batter about his ears, ceased to be tyrannical, and was gradually led to the belief that his own interests might be identical with those who practised vulgar arts, instead of the knightly profession of arms. The use of gunpowder in battle rendered wars less bloody, by keeping the combatants at a distance from each other: the modern improvements which are being made in fire-arms will have the effect of increasing that distance, and thus gradually rendering war impossible; for if the rifle be made to kill with certainty at the distance of 1,000 yards, the soldiers will refuse to appear within sight of it; and if a small arm can be made to discharge a bullet five-and-twenty times in a minute, charges of cavalry will be impossible; so that unless war be reduced to a succession of surprises, it would scarcely admit of being carried on in pitched battles. Governments

(1) Dr. Ryan in the "Aide-Mémoire to the Military Sciences," vol. ii. part 1. 1848.

(2) The recipes given by Albertus Magnus and Roger Bacon were probably derived from this work. Bacon (who died in 1278) conceals one of the ingredients under the veil of an anagram. He writes, "Sed tamen salis petræ, *luru mone cap ubre*, et sulphuris, et sic facies tonitrum et coruscationem, si scias artificium." The italics are unmeaning in their present form, but the letters will make *carbonum pulvere*, or powdered charcoal. The passage may then be translated thus:—"But nevertheless, take of saltpetre, with powdered charcoal and sulphur, and thus you will make thunder and lightning, if you know the mode of preparing it."

(3) See an essay "Sur le Feu Grégeois et sur la Poudre à Canon," by M. Lalanne, noticed in the "Annales de Chimie et de Physique" for 1842. Also a notice of the researches of MM. Reinaud and Favé, in the same work, for 1846.

would therefore be obliged to dispense with the costly luxury, reserve their big guns to announce the birth of princes, or to welcome with complimentary thunder the approach of great ones. Gunpowder will probably continue to present an available store of mechanical force to the miner and the engineer: the sportsman will still continue to use it in securing his game, and to the fire-work maker it will ever form a necessary article.

The great importance attached to gunpowder by different nations has displayed itself in a remarkable manner, for without any knowledge of the law of definite proportions, and even before the existence of true chemistry, and probably without any communication with each other, each nation has long been in the habit of using very nearly the best proportions of the 3 ingredients, viz. 1 equivalent of nitre, 1 of sulphur, and 3 of charcoal, or 75 per cent. of nitre, 11·77 of sulphur, and 13·23 of charcoal. The following statement shows the composition of different gunpowders :—

	Nitre.	Charcoal.	Sulphur.
Royal Mills, at Waltham Abbey	75	... 15	... 10
France, National Establishment.....	75	... 12·5	... 12·5
French, for Sportsmen	76·9	... 13·5	... 9·6
French, for Mining	62	... 18	... 20
United States of America..............	75	... 12·5	... 12·5
Prussia	75	... 13·5	... 11·5
Russia	73·78	... 13·59	... 12·63
Austria (Musquet)........................	72	... 17	... 16
Spain	76·47	... 10·78	... 12·75
Sweden	76	... 15	... 9
Switzerland, round powder...........	76	... 14	... 10
Chinese	75·7	... 14·4	... 9·9

In practice the ingredients used in the manufacture of every 100 lbs. of gunpowder are, saltpetre 77½ lbs., sulphur 10½ lbs., charcoal 16 lbs.=104 lbs., the extra 4 lbs. being allowed for waste.

The saltpetre as imported is unfit for the manufacture of gunpowder, as it is combined with common salt, or with salts such as nitrate of lime, which absorb moisture, and prevent the close contact and combination of the other ingredients. The loss which rough nitre sustains in refining is termed the *refraction.* It is refined by solution in an equal weight of spring or river water, which is quickly raised to a boiling heat, and after four or five hours allowed to cool; it is filtered through canvass bags, and crystallized in copper pans. The nitre is then purified a second time in a similar manner, but with a smaller quantity of water, 10 parts water being used to 14 of nitre: after the second crystallization, the water in the crystals is expelled by fusion, and the nitre assumes a delicate white appearance. The principle of this purification is founded on the greater solubility of nitre in hot than in cold water: 100 parts of water dissolve 236 parts at 207°, and only 29 at 64°; while nitrate of lime being a deliquescent salt is retained in the menstruum after the nitre has been separated by crystallization.

The sulphur is purified by a double process of fusion in gun-metal pots by a gentle heat for about four hours.

The value of gunpowder greatly depends on the quality of the charcoal. It is found to be less contaminated with foreign matters when prepared in iron cylinders, instead of charcoal-pits: the best woods for the purpose being the black dog-wood, the alder, and the Dutch white willow. It is best when newly made from seasoned wood; it should be perfectly charred, and exhibit throughout its section the same appearance, either dead black, or shining, according to the nature of the wood: it should be soft, and free from extraneous particles, so as not to scratch polished metal: it should give out no smoke when in a state of ignition, and yield no alkali to boiling distilled water. It should be stored in small quantities of 2 or 3 cwt., because in a large mass it is liable to spontaneous combustion.

The three ingredients being reduced to an impalpable powder, are mixed together in a barrel in the proportions already indicated, in which state they are conveyed to the incorporating cylinder mill in charges of 42 lbs.; each charge is moistened with 2 or 3 pints of water, according to the temperature, or hygrometric condition of the atmosphere. In this mill the runners or cylinders are 6 feet in diameter, and about 18 inches thick, weighing about 3 tons each: the circular bed in which they travel is about 7 feet in diameter: they cannot with safety be allowed to revolve more than 8 times per minute. Both runners and beds were commonly made of compact limestone or marble, but it has been found that cast-iron can be used without danger, provided the gudgeons work in gun-metal. Each charge requires to be 3½ hours in process of incorporation, so that this period regulates the quantity of gunpowder which can be manufactured at one incorporating mill. Major-General Fanshawe suggests, "whether by a greater degree of manipulation in the mixing tub, a shorter time for each charge would not suffice under the cylinders of the incorporating mill, and thus produce, without compromising the thoroughly close and compact combination of the elementary particles, a much greater quantity of gunpowder in a given time."[1]

The thorough incorporation of the ingredients is most essential to the production of good gunpowder. Considerable experience is necessary to direct the operation, and decide upon the fitness of the mixture, which at the end of the process should have a uniform grey appearance. The mixture, now called *mill-cake,* is next subjected to a pressure of about 75 tons per superficial foot, in a hydrostatic press, for which purpose mill-cake powder is placed on the bed or follower of the press, and separated at equal distances by sheets of copper, so that when taken out it is in the form of large thin solid cakes, termed *press-cake.* This is crushed between toothed rollers of different successive guages, or broken by wooden mallets into small pieces, which are put into parchment sieves pierced with holes of the size required for the particular kind of gunpowder which is being manufactured. The sieves are mounted in a frame suspended at the corners, to which a shaking motion is given. Each sieve contains two flattened spheroids of lignum-vitæ, which, by the motion given to the

(1) Aide-Mémoire to the Military Sciences, art. *Gunpowder.*

frame, continue to crush the powder until it is reduced small enough to pass through the holes of the sieve. The gunpowder is received into hair-cloth sieves, which retain the *grained* powder and allow the dust to pass through.

The next operation is *glazing*, for which purpose the gunpowder is put into a canvas cylinder, or large cask, which is made to perform 40 revolutions per minute, and by the rubbing of the grains against each other the angular points are broken off, and the grains acquire roundness, as well as smoothness and polish of surface. The latter quality is sometimes fraudulently imparted by putting a small quantity of finely powdered black-lead into the glazing-barrel.

The processes of pressing and glazing are of great importance, the one for imparting an equal degree of density to the grains, and the other a polish to their surface, by which the powder is less disposed to absorb moisture, and stands the shaking and friction of carriage better.

The last operation is to dry the powder thoroughly at the temperature of 140° or 150° Fahr. The old method of drying was by means of a *gloom-stove*, consisting of a large cast-iron vessel protruded through the wall into the drying-room, and heated by fire on the other side. The present method, which is greatly to be preferred, is to raise the temperature of the drying-room by means of steam-pipes, or to transmit a current of air previously heated in another chamber, over canvas shelves containing the damp powder.

The force of the explosion of gunpowder depends on the sudden conversion of the solid grains into gas, and the production of intense heat resulting from the action of the combustibles upon the nitre. The chief gaseous results are carbonic oxide, carbonic acid, nitrogen, and sulphurous acid; and the solid residue consists of carbonate and sulphate of potash, sulphuret of potassium, and charcoal. The maximum gaseous volume is produced by the formation of carbonic oxide and sulphurous acid with the liberation of nitrogen. With 1 equivalent of nitre, 1 of sulphur, and 3 of charcoal, the nitre yields 5 proportionals of oxygen, of which 3, combining with 3 of charcoal, furnish 3 of carbonic oxide gas, and the remaining 2 convert 1 of sulphur into sulphurous acid gas, and the single proportional of nitrogen is disengaged alone. Hence the gaseous volume produced by 130 grains of gunpowder, equal in bulk to 75·5 grains of water, or $\frac{3}{10}$ of a cubic inch, will, at the atmospheric temperature, be as follows:—

	Grains.		Cubic Inches.
Carbonic oxide	42	......	141·6
Sulphurous acid	32	......	47·2
Nitrogen	14	......	47·4
			236·2

being an expansion of 1 volume into 787·3. But as the temperature of the gases at the moment of formation must be incandescent, this volume may be estimated at 3 times the above amount, or considerably more than 2,000 times the bulk of the solid.

This theoretical account does not, however, quite agree with the products obtained by experiment, especially as regards the evolution of carbonic acid and the residuary sulphuret of potassium. Professor Graham has therefore given the following view of the results of the deflagration as being more consistent with experiment:—

Before combustion.		*After combustion.*
3 equivalents of Carbon	6 Oxygen	3 Carbonic acid.
1 equivalent of Nitre	1 Nitrogen	1 Nitrogen.
	1 potassium	1 Sulphuret of potassium.
1 „ Sulphur		

Carburetted and sulphuretted hydrogen and vapour of water are sometimes found among the products of the combustion of gunpowder: but as good gunpowder does not contain more than 1 per cent. of water to furnish the hydrogen, the quantities must be very minute. Gunpowder burns under water, so that by using a slowly-burning powder, such as is used for filling squibs, inflamed in a copper tube, the gaseous products may be collected over water in the pneumatic trough. The port-fires used by the artillery answer very well for the purpose; but in these, not only is a slow burning powder used, but the combustion is delayed by distributing the powder through a great length, and subjecting it to strong compression.

The chief use of the sulphur in gunpowder is to increase its combustibility in consequence of the low temperature at which it burns: but the larger the proportion of the sulphur, the weaker will be the gunpowder. Thus, a powder containing 12 per cent. of sulphur and 12 of charcoal, does not throw a proof shell so far as a powder containing 19 of charcoal and 9 of sulphur; but the former powder is better adapted for keeping than the latter. The rapidity of the combustion, and consequently the force of the explosion, is increased by the granulation, because, by making the charge porous, the flame can penetrate it and kindle every grain in very rapid succession. The combustion of the press-cake is very much more gradual.

The goodness of gunpowder may be tested by placing two heaps of about 60 grains each upon clean writing-paper 3 or 4 inches asunder, and firing one of them with a red-hot wire: if the flame ascend quickly with a good report, sending up a ring of white smoke, leaving the paper free from white specks, and not burnt into holes, and if no sparks fly off from it to set fire to the contiguous heap, the powder is very good: if these tests fail, the ingredients are badly mixed, or impure.

The strength of gunpowder is tested by measuring its projectile force by the *eprouvette*, which is a small strong barrel, in which a given quantity of powder is fired, and the force of expansion is measured by the action exerted on a strong spring, or a great weight. Another method is to fire a heavy ball from a short mortar, with a given weight of the powder, and to ascertain the range of projection. The eprouvette formerly used in France, was a mortar 7 French inches in calibre, which, with 3 ounces of powder, was to throw a copper globe weighing 60 lbs. to the distance of 300 feet.

Some of the effects of ignited gunpowder are truly astonishing. Count Rumford loaded a mortar with $\frac{1}{20}$th of an ounce of powder, and placed upon it a 24-pound cannon weighing 8,081 lbs.; he then closed up every opening as completely as possible, and fired the charge: the mortar burst with a tremendous explosion, and lifted up the enormous weight. In another experiment, he confined 28 grains of powder in a cylindrical space, which it just filled; and upon being fired, it tore asunder a piece of iron which would have resisted a strain of 400,000 lbs.

GUTTA PERCHA.[1] The concrete juice of a forest tree, native of the shores of the Straits of Malacca, Borneo, and the neighbouring countries. The natives had themselves discovered its valuable properties before they became known to Europeans. They constructed whips, buckets, and vessels of various kinds out of the hardened juice, and thus excited the attention of travellers to a substance which has since been applied to a vast variety of domestic and scientific purposes in this country. Their method of proceeding, however, has been of the most destructive kind, especially since the demand of the European market for this substance has had to be met. Instead of economising their treasure, as is done in the case of the caoutchouc, by tapping the tree and allowing its juice to ooze gradually from the incision, they fell the trees at once, and removing strips of bark at intervals, collect indeed a large quantity of sap at one time, but destroy all future supplies from that source. This wholesale destruction of the gutta trees, which are naturally slow of growth, must, if unchecked, necessarily involve the destruction of the traffic which is now so brisk and advantageous in this article. To put any check upon these proceedings is said, moreover, to be extremely difficult; because each set of explorers, in searching after these trees, is more anxious for present profit, than for future benefit to the trade. A very small quantity, comparatively speaking, is to be obtained by tapping, and it is evidently to the interest of the first comers to get a full supply of sap for themselves, without considering those who come after, and who might very probably cut down the trees if they had been spared previously.

The first accounts which reached us of these trees were given by Dr. Montgomerie, of Bengal, who appears to have been the first person to notice the native use of this substance: this was in 1842. In 1843, Dr. D'Almeida presented a specimen of their inspissated juice to the Royal Society of Arts, and described some of the advantages which would accrue from its use. This communication led to no results; but another, made shortly after by Dr. Montgomerie, was more successful, so that by the united efforts of these gentlemen gutta percha was introduced to public notice, and soon told its own tale to our manufacturers. They could not be blind to the advantages offered by a material possessing many of the properties of caoutchouc, with others in addition essentially its own. The abundance of the supply also encouraged invention, and in a very short time gutta percha was applied to multifarious uses, and became a valuable auxiliary in the arts.

The tree which produces this substance is from sixty to seventy feet high, and three or four feet in diameter. Its foliage is of a pale green on the upper side, and covered with reddish-brown hairs beneath. Specimens of the flowers and fruit are exceedingly difficult to be obtained. The tree flourishes luxuriantly in alluvial tracts, at the foot of hills, and forms in many places the principal part of the jungle in such situations.

From communications of Sir W. J. Hooker to the London Journal of Botany, it appears that numerous well-dried specimens of the gutta percha, though unfortunately without corollas, were sent to this country by Mr. Lobb during his botanical mission in the east, accompanied by sections of the wood, which is peculiarly soft, fibrous, and spongy, pale-coloured, and traversed by longitudinal receptacles or reservoirs, filled with the gum, forming ebony black lines. Application was then made to Dr. Oxley, of Singapore, for flowering specimens, and these were immediately supplied by him in the most obliging manner, and transmitted to England in a thin box, the top and bottom of which were made of sheets of the gum itself, (now deposited in the Museum of the Royal Gardens at Kew.) From the more accurate knowledge obtained by means of these specimens, Sir W. J. Hooker was able to refer the plant to Dr. Wright's new genus of Sapotaceæ, called Isonandra, and to name the plant *Isonandra gutta.* Fig. 1116 represents

Fig. 1116. GUTTA PERCHA.

a branch of the *I. gutta,* and various portions of the

(1) The word is a pure Malayan one, *gutta* meaning the gum or concrete juice of a plant, and *percha* the particular tree from which this is procured. The *ch* is not pronounced hard, like a *k*, but like the *ch* in the English word *perch.*—MONTGOMERIE.

blossom, as,—1, the flower scarcely expanded; 2, ditto, with the corolla expanded; 3, the pistil; 4, transverse section of the ovary; 5, vertical section of ditto; 6, the anther; 7, the scarcely matured fruit, natural size; 8, transverse section of the same.

After the natives have cut down the full-grown trees, they make rings in the bark at the distance of every ten or twelve inches, placing under each as they make it a cocoa-nut shell, or the spathe of a palm, as a receptacle for the milky sap which begins to flow immediately that the incision is made. The sap is collected in bamboos, taken to their houses, and boiled in order to drive off the watery particles, and inspissate it to the proper consistence. Boiling appears necessary when the juice is collected in large quantity, but when a small quantity is allowed to exude from a freshly wounded tree, and is collected and moulded by the hand, it consolidates perfectly in a few minutes, and has all the appearance of the prepared article.

Gutta percha when quite pure is greyish white, but it is generally brought to market of a reddish-brown hue. This is ascribed to chips of the bark, which fall into the sap and give it their colour, but in addition to this there are frequently other matters, such as saw-dust, purposely introduced as adulterants. Dr. Oxley, of Singapore, in an interesting description of this substance, first printed in a Singapore periodical in the year 1847, states that the tree which yields gutta percha was formerly very abundant on that island, but already all the large timber has been felled, and few but very small plants are to be found. "The range of its growth," he says, "appears to be considerable, it being found all up the Malayan peninsula, as far as Penang, where I have ascertained it to be abundant, although as yet the inhabitants do not seem to be aware of the fact, several of the mercantile houses there having sent down orders to Singapore for supplies of the article, when they have the means of supply close at hand. The tree is also found in Borneo, and I have little doubt is to be found in most of the islands adjacent." Respecting the wholesale destruction of the trees, the same writer observes,—"The quantity of gutta obtained from each tree varies from five to twenty catties, so that, taking the average at ten catties, which is a tolerably liberal one, it will require the destruction of ten trees to produce one picul. Now the quantity exported from Singapore to Great Britain and the continent from 1st January 1845, to July 1847, amounts to 6,918 piculs, to obtain which 69,180 trees must have been sacrificed. How much better would it, therefore, be to adopt the method of tapping the tree, practised by the Burmese in obtaining the caoutchouc from the *Ficus elastica*, (viz. to make incisions in the bark, placing bamboos to receive the sap, which runs out freely,) than to kill the goose in the manner they are at present doing. True, they would not at first get so much from a single tree, but the ultimate gain would be incalculable, particularly as the tree seems to be one of slow growth, by no means so rapid as the *Ficus elastica*. I should not be surprised, if the demand increases, and the present method of extermination be persisted in, to find a sudden cessation of the supply."

The great peculiarity which makes gutta percha convenient and valuable for a variety of purposes is, that when plunged into boiling water, it becomes so soft and plastic as to be easily moulded into any desired form, and this form it permanently retains on cooling. It was the discovery of this fact which first led the Malays to fabricate it into whips, and subsequently into basins, jugs, shoes, traces, &c. The medical profession soon became aware of its extreme value and applicability in the practice of surgery. Dr. Oxley early discovered it to be "the best and easiest application ever yet discovered in the management of fractures, combining ease and comfort to the patient, and very much lessening the trouble of the surgeon." He also employed it for bougies, capsules, tubes for syringes, &c.

Gutta percha tubing has been found extremely useful for water service, and for the conveyance of sound. Its extraordinary strength fits it for the former use in a remarkable degree. A series of interesting experiments were made two or three years ago at the Birmingham water-works, to ascertain the strength of tubes of $\frac{3}{4}$ inch diameter, and $\frac{1}{8}$ inch thickness. These were attached to the iron main, and subjected for two months to a pressure of two hundred feet head of water without being in any way deteriorated. In order to ascertain the maximum strength of the tubes, they were connected with the company's hydraulic proofing pump, the regular load of which is 250 lbs. on the square inch. At this point they were unaffected, and the pump was worked up to 337 lbs., but to the astonishment of every one the tubes still remained perfect. It was then proposed to work the pump up to 500, but it was found that the lever of the valve would bear no more weight. The utmost power of the hydraulic pump, therefore, was ineffectual to burst these tubes.

In the conduction of sound gutta percha is also found remarkably useful. Speaking tubes of this substance for the conveyance of messages are now fitted up in mines, railway stations, prisons, workhouses, hotels, and other large establishments. Partially deaf persons are found to appreciate its value: an ingenious apparatus for their use has been devised, including the distribution of the gutta percha tubing over a church or other large building, so that, by seating themselves at particular parts where these tubes terminate, such persons are able to hear distinctly the sermons or speeches delivered therein.

Gutta percha is also brought to the aid of the architect in the ornamental work of the interior of houses. It appears to be admirably adapted for cornices and centres for ceilings, also for picture-frames, and many other uses to which plaster and papier maché have hitherto been applied. It has likewise been employed for door handles and plates, for knife-handles, vases, baskets, &c., for the stopping of decayed teeth, and for printing in relief. The clear, sharp impression it receives, and the toughness of the

substance, have made it very useful in books for the blind, and in maps embossed for their benefit. In solution this substance is employed in waterproof clothing; mixed with caoutchouc and other substances it is made into a light, porous, spongy material, suited for stuffing or forming the seats of chairs, cushions, and mattresses. Springs of clocks, clasps, belts, garters, and string, are prepared from a modification of the above mixture, while moulds and balls of gutta percha are produced of a hardness sufficient to bear turning in the lathe, like wood or ivory. A varnish may also be made in which gutta percha, being the principal ingredient, may be used to give a waterproof covering to other substances.

Gutta percha dissolves at ordinary temperatures, and still better at a higher heat, in sulphuret of carbon. The solution leaves behind on a glass plate a thin coating possessing all the properties of gutta percha unaltered. Pasteboard boxes coated over with this may be made to hold water.

Electrical experiments are aided by the use of gutta percha, for it has been found by Dr. Faraday to possess high insulating power. A letter from this distinguished philosopher, published in the "Philosophical Magazine," in March 1848, gives the following among other particulars:—"A good piece of gutta percha will insulate as well as an equal piece of shell-lac whether it be in a form of a sheet, a rod, or filament; but being tough and flexible when cold, as well as soft when hot, it will serve better than shell-lac, in many cases where the brittleness of the latter is an inconvenience. Thus it makes very good handles for carriers of electricity in experiments on induction, not being liable to fracture; in the form of thin band or string, it makes an excellent insulating suspender; a piece of it in sheet makes a most convenient insulating basis for anything placed on it. It forms excellent insulating plugs for the stems of gold-leaf electrometers, when they pass through sheltering tubes, and larger plugs supply good insulating feet for extemporary electrial arrangements: cylinders of it, half an inch or more in diameter, have great stiffness, and form excellent insulating pillars. Because of its good insulation, it is also an excellent substance for the excitement of negative electricity. It is hardly possible to take one of the soles sold by the shoemakers out of paper, or into the hand, without exciting it to such a degree as to open the leaves of an electrometer one or more inches; or if it be unelectrified, the slightest passage over the hand or face, the clothes, or almost any other substance, gives it an electric state. Some of the gutta percha is sold in very thin sheets, resembling, in appearance, oiled silk; and if a strip of this be drawn through the fingers, it is so electric as to adhere to the hand or attract pieces of paper. The appearance is such as to suggest the making of a thicker sheet of the substance into a plate electrical machine for the production of negative electricity. Then as to inductive action through the substance, a sheet of it is soon converted into an excellent electrophorus; or it may be coated, and used in place of a Leyden jar, or in any of the many other forms of apparatus dependent on inductive action."

The properties thus noticed could hardly fail to bring this substance into use in telegraphic communication. Being flexible, impervious to water, and possessing insulating power, it is the most efficient of all substances as a coating or tubing for the copper wire of submarine telegraphs. Thus it aids in producing the most marvellous annihilation of time and space our age has yet witnessed. Gutta percha has been analysed by Dr. Maclagan, who obtained as its percentage composition, carbon 86·36; hydrogen 12·15; the remainder 1·49, was most probably oxygen absorbed from the air during the process of purifying it, as the substance whilst heating on the vapour bath acquired a brown colour.

Respecting the purification of gutta percha, Dr. Oxley gives a good hint to manufacturers when he says that gutta ought not to require an elaborate process: the simple boiling in water, and rolling out into sheets, whence all foreign matter can be easily picked off, is the only process he employs, and this he thinks would be generally sufficient, if manufacturers in giving their orders would take the precaution of requiring that the article should be strained through a cloth at the time of its collection, and if they would encourage the natives to do this, by offering a somewhat higher price for gutta percha so prepared. A vast deal of trouble and expense might, in his opinion, be saved in this way, and the various processes rendered unnecessary, which have from time to time been suggested for the purification of gutta percha.

The preparation of this substance for use is carried on on a large scale in the following manner. The lumps of gutta as they are received at the factory are first brought within the action of a vertical wheel, on the face of which are fixed three knives, which, as the wheel moves at the rate of two hundred revolutions per minute, rapidly cut the lumps into thin slices, discovering whatever adulterating materials may be contained therein. The gutta thus torn up is not uniform in colour or texture, but it is rendered so by the subsequent operations. It is first softened by soaking in hot water, (by which also the dirt and other impurities become separated from it,) and then thrown into a rotating machine, where it is dragged asunder by jagged teeth and reduced to fragments. These fragments fall into water, which still further tends to purify them, and are then softened into a paste in hot water, kneaded, and rolled between heated cylinders so that all parts may become thoroughly mixed and uniform. It may be then rolled out into sheets between steel rollers, or passed in the mass through heated iron cylinders, and made into tubes, or converted to the thousand purposes of ornament or use which we have briefly indicated. In the Great Exhibition gutta percha was seen in a vast variety of forms, but none were more interesting than those which illustrated the successive stages of its manufacture. The original lump, the slices, the shreds, the kneaded mass, the sheets ready for use; all appeared there. A very inge-

nious adaptation of the substance to making stereotype plates attracted much notice. A mould is taken by pressure of a page of type with woodcuts, in gutta percha; from this mould a cast is obtained on a cylinder of gutta percha, and from this last the printing is carried on. An hour, it is said, suffices to make both mould and cylinder.

GYPSUM is one of the varieties of native sulphate of lime, and is so named from γῆ, earth, and ἕψειν, to concoct; *i. e.* formed or concocted in the earth. The structure is fibrous and earthy. It is widely distributed throughout the world, and was well known to the ancients, who applied it to many of the same uses for which it is valued at the present day. In England it abounds in the London and other clays, but its great repository is in the rock commonly called new red sandstone. Numerous quarries exist in that formation, and those of Derbyshire, South Yorkshire and Nottinghamshire are in high repute. The better sorts of Derbyshire gypsum are employed in the Staffordshire potteries, as an ingredient in certain kinds of earthenware and porcelain, and also in making moulds for such articles of pottery as cannot be shaped on the common wheel. The finest pieces of this gypsum are reserved for ornamental purposes, such as vases, small statues, &c., of which a considerable manufacture exists in Derby. Gypsum in this form generally bears the name of *alabaster*,[1] and is remarkable for its softness, purity of colour, and fragile character: once soiled, its purity cannot be restored by ordinary washing, and it is also extremely liable to crack. Articles of delicate workmanship in this material are therefore preserved under glass. Alabaster abounds in the tertiary strata of Montmartre, near Paris, and sometimes it forms entire hills. In the Tyrolese, Swiss, and Italian Alps it is found upon the primitive rocks, often of the purest white, especially at Moutiers, near Mont Blanc, and near the summit of Mont Cenis.

There is also a crystallized or hydrous variety of gypsum ($CaO, SO_3, 2HO$). It is called *selenite*, from σελήνη, the moon, in reference to its soft lustre. The primitive form of selenite is a rhomboidal prism: the crystals are commonly transparent, of a sp. gr. 2·32, and of various colours, and it is so soft as to yield easily to the nail. These crystals are often disseminated in argillaceous strata, as at Alston in Cumberland, and at Shotover Hill in Oxfordshire, accompanied by shells and pyrites. These crystals are capable of division into thin plates, if split in a direction parallel to their two broad planes. This was known to the ancient Romans, who made use of these thin and semi-transparent plates instead of window-glass. A variety of gypsum, known as *lapis specularis*, furnished these laminæ of great size, sometimes five feet long. By this means, conservatories were glazed for the preservation of fruit-trees during winter, and beehives were made transparent, for the purpose, as Pliny states, of enabling the curious to see the working of those insects.

(1) There is some doubt as to the derivation of this word, but it is supposed to be from α, without, and λαβον, a handle, referring to a vase or box without handles, for containing perfumes.

Fibrous gypsum, or satinstone, is much softer than alabaster, and is fashioned into necklaces, &c. of considerable beauty.

An *anhydrous* variety of gypsum, or one containing no water, is known to the mineralogist as *anhydrite;* it is harder and denser than selenite, its specific gravity being 2·96; it sometimes contains common salt, when it is called *muriacite.* It is generally massive and lamellar, rarely crystallized, but is susceptible of division into rectangular prisms. It has been found in Derbyshire and Nottinghamshire of a pale blue tint: sometimes it is pink or reddish, and often white. It is found at Vulpino, in Italy, and hence called *Vulpinite.* The artists of Bergamo and Milan employ it under the name of *Marbre di Bergamo.*

Gypsum, when calcined and reduced to powder, can be brought to a pulpy mass by admixture with water, and is the well known *Plaster of Paris.* This mass very soon sets, or returns to the solid form, giving out, while in the act of doing so, a considerable degree of heat. Advantage is taken of this fact in the use of gypsum as a material for casting and taking impressions. The writings of Theophrastus and other Greek authors show that this use of gypsum was known to them. They distinguished two kinds of gypsum, the pulverulent and the compact; the latter was obtained in lumps, which were burnt in furnaces, and then reduced to powder. This powder, mixed with water, formed a cement for buildings, and was also used for taking impressions. Casts were taken in gypsum from the living face: from the moulds thus formed other casts were taken in wax, that soft material allowing any imperfections which had occurred in the plaster casts to be rectified. Gypsum was also employed in stucco work for wreaths, medallions, and other ornaments of ceilings, cornices, &c.

The purest gypsum is required in making casts: the best part of the crystalline gypsum rocks of Newark is well adapted for that purpose. This should be quarried in dry weather, stacked under covered sheds, and conveyed to the place of manufacture in a perfectly dry state. Here it is sorted into two or three qualities, the central part of each block, which is the finest and best, being selected. The calcining ovens are heated with billet-wood, and the gypsum, previously reduced to small pieces, is thickly strewn on the floor of the oven to the depth of five or six inches. The door is then closed, and kept in that state for twelve hours, after which it is opened, but the gypsum is left for two or three hours longer. It is then placed in covered boxes for some hours, and finally ground between stones, and run through a lawn sieve. This process gives a gypsum fit for medal-casting, and other fine purposes. Gypsum in this powdered state may be preserved uninjured for any length of time, if perfectly excluded from the air, but as this is nearly impossible, it is better not to prepare a large quantity at one time. The quality of the powder may be tested by an experienced person, simply by squeezing it in the hand: if it cohere slightly, like wheat-flour,

it is good; but if it fall to pieces immediately, it has been injured by damp. In the baking of the gypsum care must be taken not to overheat it, or it will assume the crystalline character of *anhydrite*, and not set on the addition of water. The specific gravity of anhydrous sulphate of lime (artificial) is 2·927.

Considerable judgment and care are required in mixing the gypsum with water, and in giving the plaster just the proper degree of fluidity which will cause it to enter all the lines of the mould, and not that excess which would render the finished work porous and fragile. The powder must be shaken into the water by degrees, or better still, dropped in by hand, and distributed so that it may not collect in lumps, but become gradually and completely soaked. This should be continued till the powder comes to the level of the water, if for thin plaster, and until it stands slightly above it if a strong one is required. It is left undisturbed for a few seconds, and then gently stirred with a spatula until it thickens, when it is immediately poured into the mould. Good plaster should be of the consistence of cream, and will set or become solid in ten minutes, though it is not safe to remove the mould until half an hour has elapsed. The nature of the water used will affect the setting of the plaster, for it is found to set a few seconds earlier with river-water than with spring-water; hence, where large castings are to be performed, the first quantity is mixed in river-water, the second in spring-water, to allow the necessary time for applying them. There are modes well known to the workmen of hastening or retarding the setting; for the former, hot water or salt and water can be used; for the latter, a little size, beer, or urine, mixed with water, will retard it four or five hours. But all these expedients are objectionable, as injuring the quality of the plaster.

To prevent the plaster adhering, the mould, or original, is first smeared with oil, or if marble statues are to be operated on, which would be injured by oil, then a substitute is found in first brushing the surface with white of egg, and when this is dry applying a strong solution of soap in water mixed up with a little clay. Plaster casts may be hardened, and made to look somewhat like marble, by first drying them gradually at a moderate heat, and then coating them with melted white wax. The casts are then warmed at the fire until the wax is absorbed, when a translucent appearance is given to the cast, and a considerable polish may be obtained by friction.

In all objects presented in relief, it is obvious that in order to get a copy also in relief, a hollow mould must first be made on the original, and the plaster poured into this mould. In medal-casting these moulds are often made of sulphur, but this is perhaps inferior to white wax, which gives a very perfect impression of the medal. Into the mould thus formed, plaster is poured, at first thinly, and worked into all the cavities with a camel's-hair pencil, then more plaster is added, and the whole left for half an hour to harden.

Inferior kinds of gypsum are used for building material and for floors. For the former it is burnt in kilns on a large scale, and the cement made from it is mixed with sand as well as water. For floors, the same kind of gypsum, first dried at a very gentle heat, is pulverized, and then put by itself in an iron pot, and placed over the fire. The lower particles are soonest heated, and their water of crystallization, amounting to 21 per cent. of the whole, is converted into steam, which, escaping through the incumbent mass of powder, gives it an undulatory motion; hence this process is called *boiling*, although no liquid is used. When all the moisture is driven off, the motion ceases, and the gypsum is ready for use.

Many years ago Professor Emmet[1] showed that raw or native gypsum may be rendered capable of perfect solidification without having undergone the operation of burning. If the raw gypsum be finely pulverised, and mixed with a solution of caustic potash, of carbonate or bicarbonate of potash, sulphate, silicate, or double tartrate of the same alkali, it undergoes immediate and perfect solidification. The solid plaster thus formed does not appear to differ from the burnt plaster set in the ordinary way, except, of course, in chemical composition; and it is remarkable that the solid masses when broken up and worked with fresh portions of the solutions, recover their tendency to set, even though the operation be repeated three or four times.

There is a marked difference in the time required for the operation. Solutions of carbonate and sulphate of potash, if sufficiently dilute, produce their effects so slowly as to admit of complete incorporation; whereas Rochelle salt acts as soon as the powder touches the fluid, and all subsequent motion weakens the cohesion.

It is a remarkable fact that the addition of one or two per cent. of sulphate of potash, of alum, or of borax, delays the setting of plaster of Paris three or four hours, and converts it into a stone-like body of a higher specific gravity than the ordinary set plaster. The method of making the addition of one of the above salts is, to bake the lumps of gypsum, so as to deprive them of their water of crystallization, and to quench them in a solution of one of the above salts; then to bake again at a red heat, and afterwards grind to powder. On mixing this powder up with water in the usual way it will take three or four hours to set, and will form a hard dense solid. The addition of one of the above-named salts also prevents the gypsum from assuming a crystalline character by overheating, and even allows a much higher temperature to be used in the burning without injury.

The finest pure white compact gypsum, found near Derby, is the *alabaster*, of which we have already spoken. But this is inferior to the beautiful alabaster of Italy, which is also employed in sculpture. The Italian alabaster is semi-transparent when first raised from the quarry, and is wrought into the desired form while in this state; but it is then usually rendered more opaque by being entirely surrounded and

(1) American Journal of Science and the Arts, vol. xxiii.

covered by cold water, which is gradually raised to the boiling point. The temperature is then allowed to decline to about 70° or 80° Fahr., when the object is taken out, wrapped in a cloth, and allowed to remain until dry. After this process the alabaster gradually assumes an opaque appearance. In former times alabaster was used in statuary, and some curious discoloured monuments in this material exist in some of our churches. The beautiful vases, pillars, and other ornamental works, which are turned in alabaster, require only a few tools in the working; namely, points for "roughing out," flat chisels for smoothing, and one or two common chisels, ground concave, and convex, for curved lines. The carved parts are done by hand with small gouges, chisels, &c., and are then smoothed with bent rasps and files, called rifflers, scraped with a triangular scraper, and further smoothed with fish-skin or glass-paper, and with Dutch rush used with water. In general, the smooth dead effect in carved alabaster is preferred, but where the polish of certain portions is required by way of contrast, those parts are worked with the end of a stick of deal, or other soft wood, supplied with Trent sand and water, and afterwards with a stick and putty-powder in water. The polishing of turned works is effected by taking a piece of fine soft sandstone, and applying it with water to the work, moving the sandstone all over it while it is in rapid revolution, until there is worked up a body of mud, then this mud is well rubbed with a wet rag on the alabaster, which is afterwards washed clean, and finished off with another rag charged with a mixture of putty-powder and soap and water.

Alabaster is not so often used by the lapidary as by the sculptor, but its treatment, when employed by the former, varies somewhat from the general practice with harder stones; therefore we give a short abstract of the description furnished to M. Holtzapffel by the best lapidaries:—

In working alabaster to the required forms, the lapidary first employs the slitting-mill, which is a thin plate of iron fixed on a vertical spindle, and made to revolve with moderate velocity, the edge being charged with diamond powder, and lubricated with the oil of brick. The alabaster is then roughly ground at a *roughing* or lead-mill, which is a flat circular plate of lead, fixed on a spindle, and travelling on a horizontal plane: this is abundantly supplied with coarse emery and water by means of a brush. The alabaster is moved to and from the centre of the rapidly-revolving lap, until all the marks of the slitting-mill are removed, and the stone is reduced to a flat surface. The alabaster is then smoothed at the same mill with flour emery, after which it is removed to the *wood-mill* to be smoothed. This is a disk of mahogany used with flour-emery and water: it is more effective than the roughing-mill, because more elastic, and because the slight roughnesses of its face from the rubbing up of the fibres of the wood act more quickly and satisfactorily than metal. The alabaster is now ready for polishing, which is accomplished at a *list-mill* with pumice-stone and water; but as the list, which is wound on spirally, is very elastic, flat works must be lightly applied, or they will sink into the soft face of the list-mill, and become rounded at the edges. The polishing is completed at a leather lap, or thick piece of buff-leather, pasted on a wooden disk, and supplied with fine putty-powder and water. Sometimes the naked hand, and a little moistened putty-powder, are finally used for the last polish. Amber, coral, jet, malachite, steatite, turquoise, and some other substances, are treated in nearly, or exactly the same manner as alabaster.

The cleaning of alabaster is effected as follows. The soiled object is immersed in cold spring-water for four or five days: the water is then changed, and a small quantity of lime is added, in which solution the alabaster is allowed to remain four or five days longer. It is then thoroughly rinsed, and exposed to dry in the open air. If the process fails on the first trial, it is repeated, and sometimes a third application becomes necessary. Earthenware-pans should be used, as wooden tubs stain the alabaster. Objects that consist of several pieces will be severed by this process, but can easily be re-united with plaster-of-Paris. The pores of the alabaster will also be opened, and it will exhibit its natural granular and sparkling appearance; but the more opaque effect can be restored by using putty-powder, applied with a rag or stick.

Oriental alabaster is a compact substance differing materially from the above: it is a stalagmitic carbonate of lime, of the same hardness as marble, and used for similar purposes. It is found of all shades, from white to brown, and sometimes veined with coloured zones. The magnificent Belzoni sarcophagus, purchased by Sir John Soane for 1,000 guineas, and exhibited at his museum, is of stalagmite. There are also fine specimens in the Egyptian Gallery of the British Museum.

HÆMATITE, or red iron ore, from the Greek, in allusion to its blood-red colour; but the original meaning of the term is so far lost, that mineralogists speak of *brown* and *black* hæmatite. [See IRON.] Fig. 1117 is a representation of a specimen of red hæmatite.

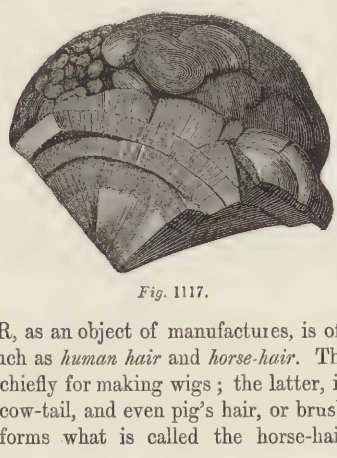


Fig. 1117.

HAIR, as an object of manufactures, is of various sorts, such as *human hair* and *horse-hair*. The former is used chiefly for making wigs; the latter, including ox-tail, cow-tail, and even pig's hair, or brushmaker's waste, forms what is called the horse-hair manufacture.

The best horse-hair is collected in the various towns of England, from ostlers and others, and sent up to London in sacks; long tail hair will fetch as much as 2*s.* per pound; short and inferior hair not more than 8*d.* Foreign hair, and that of wild cattle, is inferior to English on account of the lower feeding abroad.

When the hair is received at the factory it is sorted into colours, such as *best* and *seconds black* or *grey;* into qualities, as *soft* or *hard,* and into lengths suitable to the three purposes of *curling, spinning,* and *weaving.*

Curled hair, such as is used for stuffing sofas, chairs, carriage-seats, &c., is prepared from the sorted short black or short grey. It is first *carded* between two large coarse cards, one of which is fixed at an angle of about 45° to a bench, and the other is worked by the hand, the operator sitting all the time. By this system of rough combing the hair is freed from scurf and dirt, and disentangled. The next process, called *tipping,* is performed by a boy, who, kneeling on the floor, with a cane in each hand, tosses about a quantity of carded hair, so as to let it fall in a tolerably regular tuft or *top,* which he consolidates by inflicting upon it a rapid succession of blows. One of these tops is then taken by a man, who attaches it to a wheel, which he causes to rotate rapidly by swinging round the top, and he thus spins or *curls* it into a hard rope; but before he has quite finished one top he works another into the loose ends, and then spins the second, and in this way he proceeds until he has spun a dense line of considerable length. He stops the wheel every now and then to wind up the finished rope upon it, and when a certain length has been spun, it is taken off the wheel, tied up into a bundle, and with other similar bundles *steeped* in a cistern of cold water for three or four hours; then taken out, and while still wet put into a very hot oven, the heat of which is gradually let down during about twenty-four hours. The ropes are next *opened* by slightly untwisting in the opposite direction, then *towsing* or picking to pieces, when the hair will be found to possess that remarkable springy character which so well fits it for stuffing cushions, &c. The short sorted white hair is also used for brushes.

Hair of medium length is spun into a coarse thread, which is employed in weaving a coarse horse-hair cloth, such as is used for nose-bags for horses, filtering bags, and for some other purposes. This hair is also spun into clothes-lines.

The long hair is sorted a second time, and straightened by being thrown upon heckle points and pulled out many times. It is further separated into lengths by fixing the *heads* or thick ends of the hairs between the teeth of a couple of cards, and pulling out the longest ends by the points or opposite ends. By repeating this process two or three times, the hairs are separated into lengths with great precision. These are tied up by the heads into tufts, and are used in weaving damask hair-cloth, such as is used for covering sofas, chair-bottoms, &c. In this kind of cloth the warp is of black linen yarn, and the weft of hair, which is thrown in with a long hooked shuttle or rod, with a catch-hook at the end. The shuttle is passed into the shed of the warp, and a child, placed on one side of the room, presents a hair to the weaver near the selvage, who, catching it with the hook of his shuttle, draws it out on the other side: the batten is then driven home twice, and another shed or shuttle-way opened by the treddles: thus each weft thread is formed by a separate hair. The hairs are kept in a bundle in a vessel of water, to make them sufficiently supple for weaving. When the web is complete it is hot-calendered to give it lustre. In this way horse-hair cloth is produced from 14 to 36, and even 40 inches in width. The latter width is, however, very unusual, and a long time is required to pick out and collect a sufficient number of hairs for the purpose.

A hair-cloth is woven for sieves, boys' caps, and other purposes. The long white hairs are used for stringing pearls, for fiddle-bows, for fishing-lines, &c.

Horse-hair can be bleached nearly white, and it takes various dyes tolerably well.

Horse-hair wigs are made of what is called *dead* hair, or the hair from horses which are out of condition, so that the nutriment to the hair being stopped, it dies and assumes a chalky appearance. A mixture of black and white hairs produces a grey. The dealers in hair know their markets so well, that they will not only separate live from dead hair, foreign from native, but they can tell with tolerable accuracy what part of Great Britain any specimen submitted to them may come from.

HAIR-PENCILS. See Brush, p. 254.

END OF THE FIRST VOLUME.